NEVADA BUREAU OF MINES AND GEOLOGY

BULLETIN 58

GEOLOGY AND MINERAL DEPOSITS OF MINERAL COUNTY, NEVADA

By Donald C. Ross

Prepared cooperatively by the United States Geological Survey

MACKAY SCHOOL OF MINES
UNIVERSITY OF NEVADA, RENO

1961

CONTENTS

ILLUSTRATIONS

TABLES

FOREWORD

One of the projects undertaken as part of the cooperative program between the Nevada Bureau of Mines and the U. S. Geological Survey is the reconnaissance study, on a county-by-county basis, of the mineral resources and geology of Nevada. The purpose of this project is to produce sufficiently detailed maps to aid in the discovery and exploration of economic mineral deposits in the State. Such maps will indicate, also, areas where more detailed field studies should be made.

Mineral County is one of Nevada's oldest and most historic mining areas. It contains such well-known pioneer metal mining districts as Aurora, Candelaria, and Rawhide. It is noted, also, for the first discovery of borax in Nevada, by "Borax" Smith in 1872 at Teels Marsh. Although the borax industry has since shifted to southern California, this discovery was the beginning of production of borax in large quantities in the United States. In recent years the Nevada Scheelite mine, producing tungsten ore, and the Kaiser (Baxter) mine, producing fluorspar, have been the major mining operations in the county.

During its mining history, Mineral County has produced approximately 75 million dollars of mineral wealth. The major production has come mainly from silver, gold, tungsten, and fluorspar, with appreciable amounts from copper, borax, mercury, and lead.

Nevada Bureau of Mines Bulletin 58, "Geology and Mineral Deposits of Mineral County, Nevada," is one of the series of county reports that will cover the entire State. It has been prepared by Donald C. Ross, Geologist, U. S. Geological Survey, who did his field work in the summer of 1956. The bulletin describes the mining history and mineral resources of Mineral County. It should be of great assistance to all persons interested in the development of the mineral resources of the county.

VERNON E. SCHEID, *Director,*
Nevada Bureau of Mines.

July 1961
Mackay School of Mines
University of Nevada

GEOLOGY AND MINERAL DEPOSITS OF MINERAL COUNTY, NEVADA

By DONALD C. ROSS

ABSTRACT

Mineral County, Nevada, is in the western part of the State near the western margin of the Basin and Range province. The county has an arid to semiarid climate and the topography is characterized by the alternation of elongate ranges and valleys.

About 30,000 feet of structurally complex calcareous, clastic, and volcanic rocks of Triassic and Jurassic age exposed in the central part of the county are flanked on the south by a few thousand feet of calcareous and clastic rocks of Cambrian, Ordovician, and Permian age. Intrusive into this sequence are granitic rocks, chiefly quartz-monzonite, which are probably satellitic to the composite Sierra Nevada batholith of Cretaceous age. Overlying the Paleozoic and Mesozoic rocks are extensive areas of Cenozoic volcanic rocks ranging in composition from basalt to rhyolite. Many of the felsic volcanic rocks are believed to be welded tuffs and some of the mafic rocks, notably those in the south part of the county, are olivine trachybasalts with a high content of potash and soda.

The structural history of the county includes several periods of folding and faulting, among them a major orogeny that began in early Jurassic time and was accompanied by much thrusting. Cenozoic deformation has consisted chiefly of normal faulting, and some of the ranges, notably the west front of the Wassuk Range, are blocked out by these faults. Movements along faults, during earthquakes as recent as 1954, show that the area is still tectonically active.

Mineral deposits are varied and the total production of the county to 1956 was about $75,000,000, mostly in silver, gold, and tungsten. Most of the silver and gold was extracted from the fissure-vein deposits of the Aurora and Candelaria districts, which were active in the late 1800's. Tungsten has come chiefly from the contact metamorphic scheelite-bearing tactite deposits of the Nevada Scheelite mine since 1950, and from scheelite-bearing quartz veins of the Silver Dyke system during World War I. Other metal production includes copper (from the Santa Fe district during World War I), lead, mercury, zinc, iron, and

manganese. Prospecting activity has revealed small amounts of uranium, but none had been produced to 1956. Production of nonmetallic minerals began in the 1860's when salt was mined from the playa deposits and was used in the extraction of ores. In 1872 borax was discovered in Teels Marsh (the original discovery in Nevada) and shortly after at Rhodes Salt Marsh. These two playas were important borax producers for about 20 years until the Death Valley, California, discoveries. Sodium sulfate and sodium carbonate also have been extracted in small amounts from the playa deposits. Nearly $6,000,000 in fluorspar had been produced from a fissure vein deposit at the Kaiser (Baxter) mine from the 1930's until 1957 when the mine was shut down. Other nonmetallic production includes barite, sericitic clay, gypsum, "bentonitic" clay, and andalusite.[1]

INTRODUCTION

Mineral County was created in 1911 by taking 4,144 square miles of territory from the northeastern part of Esmeralda County, one of the original counties of Nevada named from the Esmeralda (Aurora) district. A part of this new county was ceded to Lyon County in 1933 because of the difficulty of access to the Mineral County seat at Hawthorne from the agricultural areas along Walker River. Since that time the area of Mineral County has remained at 3,734 square miles.

LOCATION, ACCESSIBILITY, CULTURE

Mineral County abuts against the southwest boundary of Nevada and is readily accessible by the network of hard-surfaced highways shown on figure 1. In addition to the U. S. and State highways, numerous roads ranging from wide, well-graded gravel roads to mere tracks in the sagebrush are present throughout the county. The combination of mining and prospecting activity, and a climate that favors preservation of roads has resulted in a rather substantial network of good desert roads, but a 4-wheel-drive vehicle greatly increases the access possibilities. The better roads of this network are shown on plates 1 and 2.

A branch rail line provides service to the county at Schurz, Thorne, Luning, and Mina, the terminus of the line. A regularly scheduled bus service also operates along U. S. Highway 95, and daily airline service is available from Reno and Las Vegas to Hawthorne.

[1]As of publication date minor production of iron ore at the Iron Gate and Sullivan mines constituted the only mining activity in Mineral County (editors).

In 1956 the principal activity in the county was the operation and maintenance of the Naval Ammunition Depot at Hawthorne, where a major portion of the population of Hawthorne and the adjoining community of Babbitt (a Naval housing development) is employed by the U. S. Navy. Mining, which in the past has dominated the economy of the county, in 1956 was small-scale and of an extremely sporadic nature. Only two mines were significant producers in 1956—the Nevada Scheelite mine (tungsten), and the Kaiser (Baxter) mine (fluorspar)—and both of these mines shut down in February 1957. Agriculture has always been of minor importance in Mineral County, but it is locally important in the vicinity of Schurz. Cattle are grazed in the central and southern part of the county.

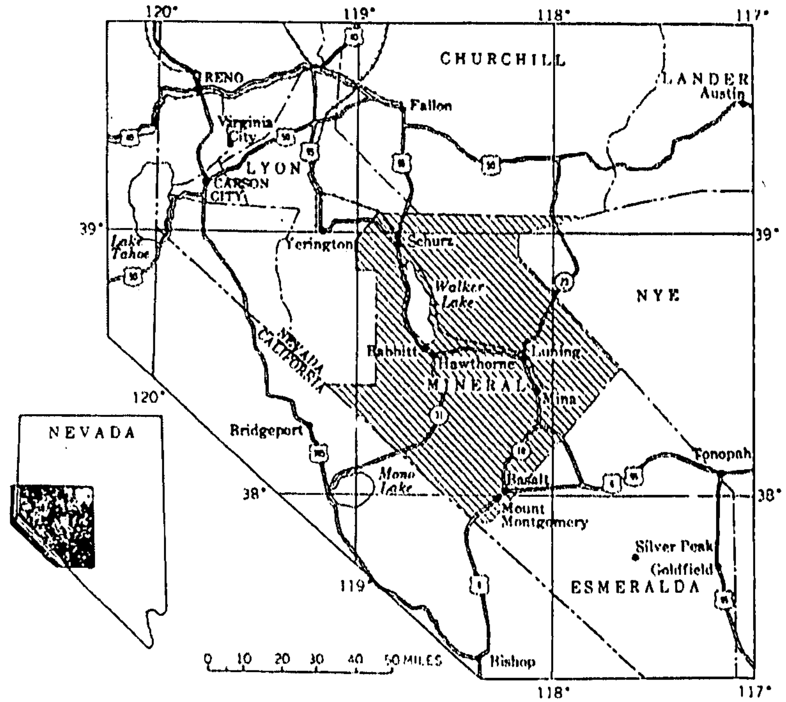


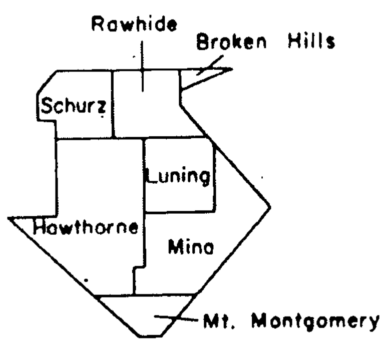
FIGURE 1. Index map of Mineral County, Nevada.

The population of the county in 1950 was 5,560, and of these 4,721 resided in the Hawthorne area. The rest of the county population was chiefly at Mina, Schurz, Luning, the Nevada Scheelite camp, and the Kaiser mine camp. In addition a few people live on ranches and at other mine properties. Table 1 shows the county population figures for the last three censuses. Two things are particularly noteworthy in the figures: (1) the increase in total county population from 1940 to 1950 in the Hawthorne area which reflects the increased importance of the Naval Ammunition Depot to the county economy, and (2) the change of population in Mina which reflects the fluctuation in mining in the county, as Mina has been the center of much of the mining activity of recent years.

TABLE 1. Census figures for Mineral County, Nevada*

	1950	1940	1930
Mineral County	5560	2342	1863
Broken Hills township	23	20	------
Hawthorne township	4721	1229	------
Hawthorne	(1861)	.. ..	†(1200)
Babbitt	(2464)	.. ..	------
Luning township	38	38	------
Mina township	274	504	†400
Mt. Montgomery township	27	51	------
Rawhide township	46	66	------
Schurz township	431	434	------

*1960 census figures show Mineral County with a population of 6,329; Hawthorne area, 5,277; and Mina, 460 (editors).
†Approximate.



Key to the townships used for census purposes.

Essentially all the population of the Broken Hills township was at the Kaiser mine camp, and the population of the Rawhide township at the Nevada Scheelite camp; Mina and Luning hold nearly all the population of their townships, and Mount Montgomery township includes the settlements of Basalt and Montgomery. The population of Schurz township includes the somewhat more scattered population in the agricultural area north of Walker Lake.

RELIEF AND DRAINAGE

Mineral County has an alternation of linear to irregularly shaped mountain ranges and irregularly shaped alluvial valleys. The most prominent range is the Wassuk Range, whose summit is Mount Grant (11,239 feet), the highest point in the county. The lowest point in the county is Walker Lake where the lake level was 3,993 feet in 1955. Therefore, the maximum relief in the county is 7,246 feet in a horizontal distance of only 5 miles.[2] Except in the Wassuk Range altitudes of more than 9,000 feet are uncommon, and since the valleys range from 4,000 to 5,000 feet in altitude, the general relief of the county is less than 5,000 feet.

Water is scarce throughout most of the county. The course of the Walker River is only about 15 miles long within the county before the river flows into Walker Lake. Walker Lake has no outlet and is notably saline, particularly at the southern end. The lake in 1956 was about 19 miles long and had a maximum width of about 7 miles. The lake level has dropped considerably since 1909 (the date of the Hawthorne 1° quadrangle) and the shape of the lake has been noticeably changed, particularly at the shallow north end. Presumably this loss in volume of the lake is in part the result of the increased usage of Walker River water, chiefly for irrigation. Water supply in the rest of the county is limited to the several small snow- and spring-fed streams on the east flank of the Wassuk Range, to Bodie Creek near Aurora, and to scattered springs and wells, most of which are shown on plate 1. Many of the early mining activities had to depend on transported water. Candelaria, for example, was supplied from the White Mountains by a 27-mile-long pipeline.

CLIMATE

Mineral County has an arid to semiarid climate with a wide range of temperature. Some climatic data for the county are summarized on table 2. As the table shows, the higher elevations receive more precipitation than the valleys. The Wassuk Range receives appreciably more precipitation, chiefly as snow, than

---

[2]The elevations given in this paragraph and elsewhere in the report were taken from recently published maps which cover parts of Mineral County, and differ from the elevations of those same points as shown on plates 1 and 2 which are based for the most part on the Hawthorne 1° quadrangle map printed in 1909.

is recorded by the meteorological stations. Aside from the Wassuk Range, snow generally does not restrict access in the winter except for short periods after storms.

TABLE 2. Climatic data for Mineral County, Nevada*

Station	Altitude (feet)	Years of record	Temperature (in degrees Fahrenheit) Jan. avg.	July avg.	Max.	Min.	Precipitation (in inches) Annual	Monthly avg.
Basalt	6300	4	25	71	102	—20	7.1	....
Hawthorne–Babbitt	4400	15	34	75	107	—6	3.95	....
Mark Twain (Aurora)....	7400?	3	26	67	94	—6	7.08 (1952)	....
Mina..............	4500	40	32.4	78	110	—22	3.45	0.15–0.48
Schurz...........	4100	19	31.3	73.4	109	—24	5.68	0.32–0.65
Thorne	4200	29	34.3	77.3	109	—16	†3.08	0.11–0.44

*Lowest recorded annual rainfall in Nevada is 3.07 inches at Clay City in Nye County on the southwestern boundary of the State.

†Source of data—Climate and Man, 1941 Yearbook of Agriculture, U. S. Department of Agriculture, 1942; and Climatological Data Summaries for Nevada for 1949–1952, published by the U. S. Department of Commerce.

VEGETATION

The vegetation is typical of the arid to semiarid Basin and Range province. Sagebrush and other desert shrubs grow on the lower slopes and in the valleys. Mixed juniper and piñon pine forests are found higher in the ranges, except for the Pilot Mountains and Cedar Mountain, which have almost entirely a juniper forest. In addition to juniper and piñon pine, mountain mahogany is locally abundant in the higher parts of the Wassuk Range and trees of the poplar family grow along streams and near springs, particularly on the east side of the Wassuk Range. Lodgepole and Jeffrey pines are scattered along Bodie Creek, and Jeffrey pine is locally common in an area northwest of Fletcher where the pre-Esmeralda volcanic rocks are altered and bleached. The abundance of Jeffrey pine combined with the sparseness of other vegetation at this locality suggests that the alteration of the volcanic rocks has produced an acid soil condition that is favored by the Jeffrey pine.

The desert vegetation of the lower altitudes is varied, but sagebrush is by far the most common plant. Many of the desert plants bloom in the spring and create a rather spectacular color display when there has been sufficient winter moisture.

Figure 2 shows the distribution of forest cover in the county, and the relation of the cover to the topography. In general the forest cover is limited to altitudes above 6,000 to 7,000 feet; the notable exception is the east slope of the Wassuk Range where trees grow at altitudes as low as 5,000 feet because of the greater abundance of water.

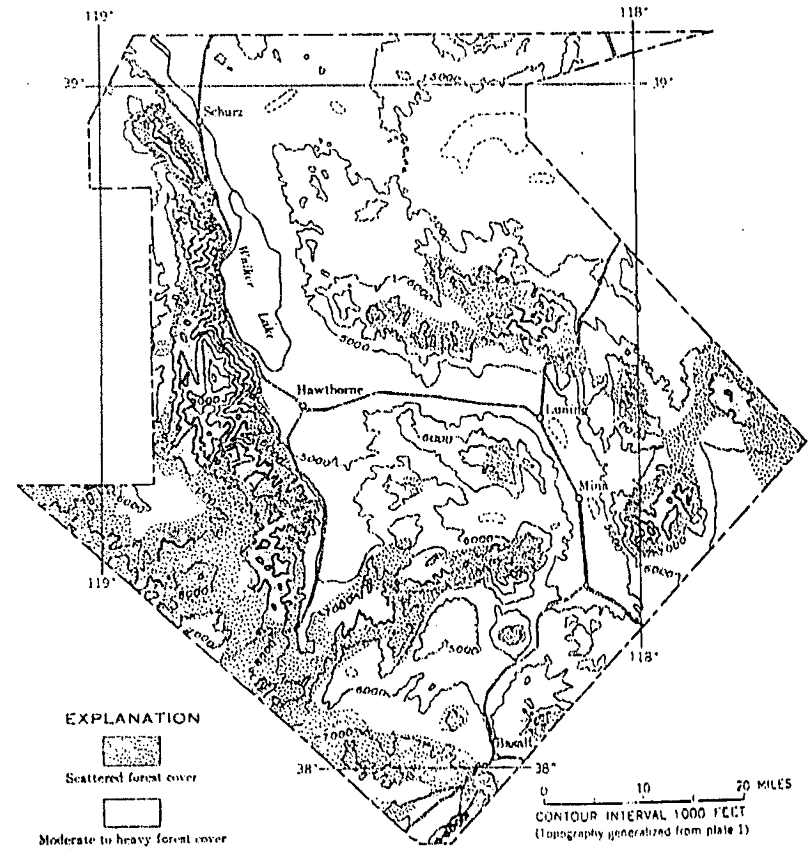


FIGURE 2. Forested areas in Mineral County (juniper and pinon pine). Data from aerial photographs.

PREVIOUS WORK

Between 1866 and the early 1900's several brief references were made to the geology of the Mineral County area, chiefly in connection with the fossiliferous Mesozoic rocks of the Gabbs Valley Range and the Pilot Mountains. The first of these references included mention of Triassic fossils from the Volcano Peak area of the Gabbs Valley Range by J. D. Whitney (1866). Spurr (1903) also presented brief descriptions of the geology of some of the ranges following a 5-month reconnaissance of a large area in 1899. Of the several other reports the first to have more than a very brief account of the geology and ore deposits of parts of the county is the work of J. M. Hill's 1912 reconnaissance (1915). He described the geology and ore deposits of the Aurora, Silver Star, Santa Fe, and Hawthorne districts and presented reconnaissance geologic maps of the first three districts. The Santa Fe district was studied in further detail and a geologic map was prepared in 1916–1917 by C. W. Clark (1922). Very brief descriptions of some of the scheelite-bearing tactite occurrences in the county (Queen, east slope Pilot Mountains, east slope Wassuk Range) are included in F. L. Hess and E. S. Larsen's study of the contact metamorphic tungsten deposits of the United States (1921). The Candelaria district and the Cedar Mountain area were studied in the early 1920's by Adolph Knopf with emphasis on the ore deposits (1921, 1922).

The first geologic study of a large area of the county began in 1922 as a reconnaissance survey of the Hawthorne and Tonopah 1° quadrangles by H. G. Ferguson and S. H. Cathcart. This work continued through the field season of 1924, and then was carried on intermittently in later years. As part of this work, Foshag (1927) published a short article with an accompanying geologic map on the quicksilver deposits of the Pilot Mountains. Also in 1927, S. W. Muller began detailed work on the Triassic and Jurassic rocks of the Gabbs Valley Range and the Pilot Mountains. In the early 1930's Ferguson and Muller began a joint detailed study of the structurally complex areas of Triassic and Jurassic rocks in the county. The most significant features of these investigations are contained in a report on the Mesozoic stratigraphy of the Hawthorne and Tonopah quadrangles (Muller and Ferguson, 1939) and another on the structural geology of the same area (Ferguson and Muller, 1949). The latter report includes a 1:250,000-scale map of the pre-Tertiary units of the two quadrangles, and detailed geologic maps of the major areas of Triassic and Jurassic rocks. Geologic maps of the Mina and Coaldale 30-minute quadrangles at a scale of 1:125,000 have been published recently as a result of the earlier reconnaissance and the later detailed work (Ferguson, Muller, and Cathcart, 1953, 1954).

Several other reports are concerned more specifically with the mineral deposits of the county. E. H. Bailey and D. A. Phoenix (1944) described the quicksilver deposits of the county in a report on the quicksilver deposits of Nevada. This work was followed by a report on the quicksilver deposits of the Pilot Mountains by Phoenix and J. B. Cathcart (1952). R. G. Reeves, F. R. Shaw, and V. E. Kral have published a report (1958) that describes the iron deposits of the county. Specific mine area descriptions have been published on the Silver Dyke (tungsten) by P. F. Kerr (1936), the Kaiser (Baxter) fluorspar mine by Thurston (1946), and the Nevada Scheelite mine (tungsten) by R. W. Geehan and R. R. Trengove (1950). Three works of a more general nature concerning the mineral deposits of the county are: (1) F. C. Lincoln's report (1923) on mining districts of Nevada, which abstracts information on location, history, production, and geology; (2) W. O. Vanderburg's report (1937) based on a reconnaissance of the mining districts of the county in 1936, which gives a good picture of the mining activity in the various districts in the mid-1930's, but contains very little geology; and (3) B. J. Couch and J. A. Carpenter's compilation of the available data on mineral production by district and county for Nevada for the period of 1859 to 1940 (1943). Numerous brief descriptions of the various mining districts are also found in short articles in mining journals, particularly during those years when the districts were active; some of these references can be found in a bibliography of Nevada geologic literature by V. P. Gianella (1945).

Investigations of a more general nature include reports on the earthquakes at Cedar Mountain in 1932 (Gianella and Callaghan, 1934) and in the Excelsior Mountains in 1934 (Callaghan and Gianella, 1935).[3]

FIELD WORK

The field work on which this report is based actually started in 1922 with the reconnaissance of the Hawthorne and Tonopah quadrangles by Ferguson and Cathcart. This work and the detailed work in the 1930's of Ferguson and Muller furnished most of the data for plate 2 (see Index map on plate 2 showing sources of geologic data).

In the summer of 1956 the writer and Frank J. Kleinhampl spent 5 man-months completing the geological reconnaissance of Mineral County. The work consisted of mapping the areas in the county that are not within the Hawthorne and Tonopah quadrangles, field checking doubtful areas within the previously mapped portion of the county, and examining mining districts. The new data were plotted on air photos, which are available for the entire county, and from these photos the data were transferred to topographic bases.

[3]A report by B. M. Page on the geology of the Candelaria mining district was published in 1959, after the Mineral County report was completed. Page's report contains a detailed geologic map (scale 1:4,800) and descriptions of the geology and mineral deposits of the district.

ACKNOWLEDGMENTS

I want particularly to thank H. G. Ferguson for his guidance and counsel during the course of this project. The large amount of field work done by Ferguson, Muller, Cathcart, and their associates in the county (see inset, pl. 2) also deserves special attention, for this work and the resulting publications provided most of the data contained in this report.

Special thanks are due Captain W. J. Ritcher, Commander R. M. Hill, and the officers and men of their command at the Naval Ammunition Depot at Hawthorne, Nevada. Their friendly cooperation in providing housing and other services greatly aided the field work and is here gratefully acknowledged.

I wish also to thank Frank J. Kleinhampl for his considerable help during his association with the project in July and August of 1956.

GEOLOGIC FORMATIONS

PRECAMBRIAN OR LOWER PALEOZOIC ROCKS

Schist of the White Mountains

Schistose metamorphic rocks underlie about 1 square mile of the southern tip of Mineral County at the north end of the White Mountains. These rocks are the northernmost outcrops of an extensive belt of metamorphic rocks exposed along the west flank of the White Mountains.

The outcrops are commonly dark red and brown. Schist is the most common rock, and it is commonly spotted with quartzo-feldspathic clots as much as several millimeters in diameter in a micaceous groundmass. Less abundant are siliceous hornfels, calc-hornfels, and marble. The schist and hornfels sequence is generally thin bedded and was probably derived mostly from fine-grained clastic rocks with a minor admixture of calcareous material.

The age of these rocks is unknown. The nearest fossiliferous rocks of somewhat comparable lithology are the Lower Cambrian rocks on the south flank of Miller Mountain about 10 miles to the northeast. The metamorphic rocks of the White Mountains were considered by Anderson (1937, p. 61–62) to be partly Cambrian but mostly Precambrian. Anderson's work, however, was of a reconnaissance nature and the age estimate is based on data from the southern part of the range at least 20 miles south of the Mineral County exposures. It is therefore best to refer to the schistose rocks as "Precambrian or lower Paleozoic" pending detailed work in the northern White Mountains.

PALEOZOIC ROCKS

Cambrian

Miller Mountain formation

The Miller Mountain formation was named by Ferguson, Muller, and Cathcart (1954) from exposures on the south flank of Miller Mountain. The formation is exposed over only about 1 square mile within the county, but the continuation of this outcrop area underlies about 5 square miles in adjacent Esmeralda County. In addition a small area southwest of Mount Montgomery in the southern part of the county is underlain by rocks that are tentatively correlated with the Miller Mountain formation.

About 5,600 feet of beds are exposed on the south side of Miller Mountain. The base of the formation is not exposed, the upper part is overlain by Tertiary rhyolite, and the formation is faulted, so this section is only a partial thickness of the formation. Probably less than 1,000 feet of possibly correlative rocks are exposed in the area southwest of Mount Montgomery.

Lithology. The rocks at the type locality are a contact metamorphic sequence of marble, spotted siliceous hornfels, and calc-hornfels. The major units are easily identifiable on the air photos, but on the ground considerable lateral variation also is evident, and sections measured in adjacent canyons would be considerably different. The formation was not studied in sufficient detail to determine whether this lateral variation is the result of intertonguing or deformation.

About half the formation consists of white to gray marble (less commonly yellowish orange), which is in part dolomitic. The marble is generally massive, but in part thin bedded. The surface of one 450-foot-thick marble unit is locally pitted where calcite has been removed by weathering, leaving irregular lenses and thin layers of dolomitic and siliceous material that stand out in relief. The next most abundant rock type is medium-gray to dark-gray, thin-bedded to massive, spotted, siliceous, and argillaceous hornfels. Thinly laminated to very thin-bedded calc-hornfels, in various shades of green, brown, red, and gray, makes impressive striped outcrops. The calc-hornfels is commonly interbedded with marble in beds a few inches to a few feet thick. Some coarser lenses and layers of grossularite-epidote tactite also are present.

The rocks exposed southwest of Mount Montgomery, which are possibly correlative with the Miller Mountain formation, are chiefly slate and calc-hornfels with lesser amounts of marble.

Gray and green slate predominates and is generally more calcareous to the east, where laminated greenish calc-hornfels is common. Except near the east end of the outcrop, the dips are gentle. At the west end of the outcrop, a marble unit of unknown thickness appears to underlie the slaty rocks.

Fossils, age, and correlation. Fragments of mesonacid trilobites indicating an Early Cambrian age were collected from a shaly unit in the upper part of the section in 1923 or 1924 (Ferguson, Muller, and Cathcart, 1954). The writer and Kleinhampl, in the summer of 1956, found trilobites abundant in an argillaceous and siliceous hornfels unit (probably the unit from which the earlier collection was taken) about 500 feet from the north end of the exposed section. According to A. R. Palmer (written communication, 1958) of the U. S. Geological Survey who studied the collection:

"The collection contains at least one new trilobite, and specimens identical to the trilobite described from this locality as *Bathyuriscus batis* by Walcott (1916) and assigned to the Lower Cambrian. This trilobite is now identified as *Ogygopsis* cf. *O. klotzi* Rominger."

Confirmation of the Early Cambrian age of the collection has been obtained by C. A. Nelson of the University of California at Los Angeles who made a larger collection at the same locality and reports (written communication, July 1957) finding *Ogygopsis* associated with olenellid trilobites.

No definite correlations of the Miller Mountain rocks can be made, but the lithologic similarity to the Silver Peak group of the Silver Peak quadrangle (Turner, 1909), the Gold Hill formation of the Round Mountain quadrangle (Ferguson and Cathcart, 1954), and the Cambrian(?) rocks of Lone Mountain in the Coaldale quadrangle (Ferguson, Muller, and Cathcart, 1953) suggests a correlation. The spotted hornfels—calc-hornfels—marble assemblage of unknown but possibly early Paleozoic age in the Benton Range (Rinehart and Ross, 1957), about 30 miles southwest of Miller Mountain, also is strikingly similar to the Miller Mountain formation.

Ordovician

Slate and chert

Ferguson, Muller, and Cathcart (1954) applied the name "Palmetto formation" to the Ordovician rocks of Mineral County in the report of the Mina (30-minute) quadrangle. The name "Palmetto formation" was first used in the Silver Peak quadrangle by Turner (1902, p. 265–266) for a sequence of dark-colored, thin-bedded cherts which contained layers of gray

graphtolitic slates, and lesser amounts of reddish slate and limestone. The formation, however, was never adequately defined; no map was ever published showing the extent of the formation in the Silver Peak area, no thickness was given, and no type section was designated beyond the broad reference to the Palmetto Mountains. For these reasons it seems best to limit the term Palmetto to the Silver Peak area until such time as detailed work determines the extent and relations of the formation. In this paper the terms "Ordovician rocks" or "slate and chert" will be used in lieu of a formal name in referring to rocks of Ordovician age in Mineral County.

Ordovician rocks are exposed in several small areas, which total about 20 square miles, chiefly in the Candelaria Hills and on the slopes of Miller Mountain. This same belt of outcrop extends discontinuously east into the Monte Cristo Range in Esmeralda County.

The thickness of the rocks of Ordovician age is undetermined but it may exceed 4,000 feet. The base of this group of rocks is everywhere concealed by volcanic rocks or alluvium.

Lithology. The Ordovician rocks consist chiefly of dark-colored slate and chert, and lesser amounts of limestone, dolomites, and sandstone. The Ordovician rocks near Candelaria are chiefly interbedded black chert and slate with lesser amounts of sandstone; limestone is also present and crops out only in the cores of anticlines. The rocks exposed on Miller Mountain, presumably lower in the section, are largely slate with interbedded gray limestone (in part silicified) and chert.

Figure 3 shows a columnar section that was estimated, from an exposure on the north flank of Miller Mountain near the west end of the outcrop area, by H. G. Ferguson (written communication, 1956). This section is broken by faults, probably small, but of indeterminate displacement.

Fossils, age, and correlation. Graptolites are locally abundant in the slates and several genera considered to be of Middle Ordovician age have been identified by E. T. Kirk of the U. S. Geological Survey.

The graptolitic slate and chert assemblage of Mineral County is part of the western (clastic) facies of the Ordovician in Nevada. Formations with a similar gross lithology, probably at least in part correlative with the Ordovician rocks of the county include the Palmetto formation of the Silver Peak area (Turner, 1902, p. 265–266), the Toquima formation in the Manhattan district (Ferguson, 1924, p. 20–25), and the Vinini formation of

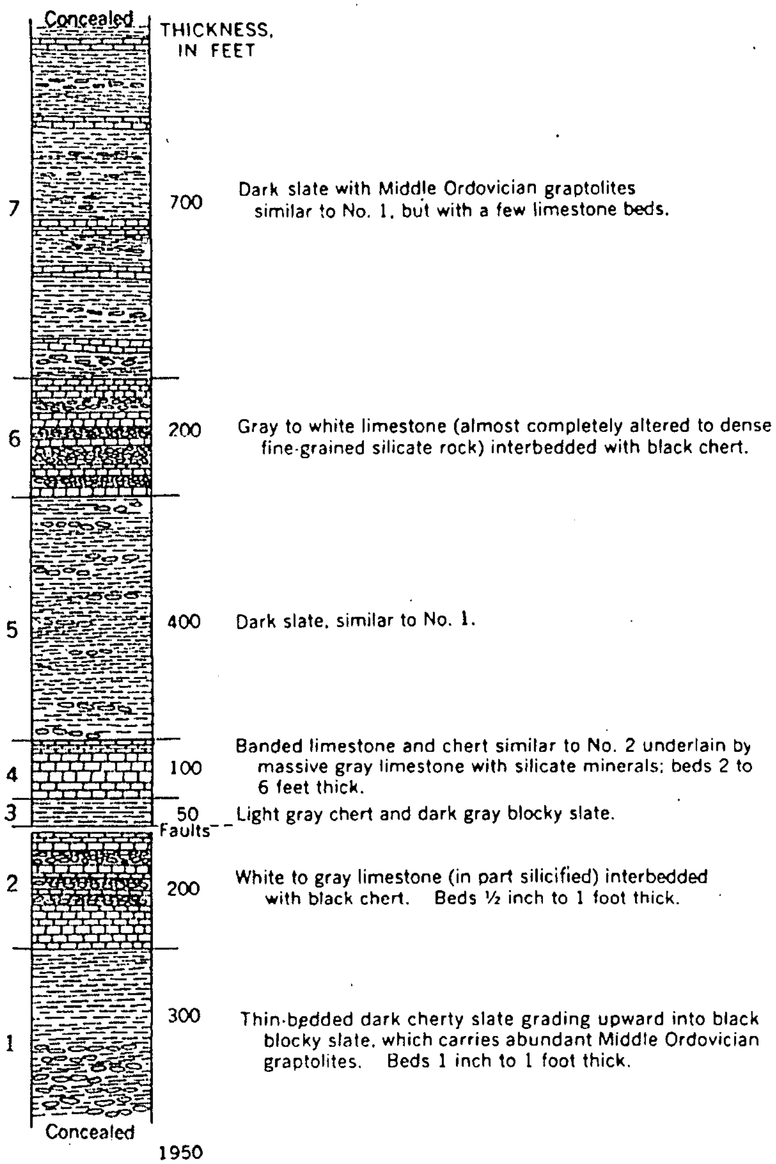


FIGURE 3. Partial columnar section of the Ordovician rocks, north flank of Miller Mountain, Mineral County, Nevada (generalized from unpublished data of H. G. Ferguson).

the Roberts Mountains (Merriam and Anderson, 1942, p. 1693–1701). These formations are predominantly slate and chert, with various admixtures of volcanic rocks, limestone, and sandstone. The graptolitic Ordovician rocks in the eastern Sierra Nevada (Rinehart, Ross, and Huber, 1959, p. 941) about 50 miles southwest of Candelaria are probably also in part correlative with the Ordovician rocks of Mineral County, although the Sierra Nevada section contains a much higher percentage of sandstone.

Permian

Diablo formation

The Diablo formation was named by Ferguson, Muller, and Cathcart (1953) from Mount Diablo, a local name for one of the minor prominences of the Candelaria Hills (it is not identified on the topographic map of the area). The formation crops out as a thin, discontinuous band that extends westward for about 10 miles from a point near the county line southeast of Candelaria.

The maximum thickness of the formation within Mineral County is not more than 200 feet, but east of the county line a dolomitic facies is about 400 feet thick. Locally the Diablo is absent where it was removed by erosion prior to deposition of the Triassic rocks. The Diablo overlies the Ordovician rocks with a marked angular discordance.

The Diablo formation is made up chiefly of sandstone and grit, which consist largely of quartz and dark chert fragments from the underlying Ordovician rocks. Near Candelaria the formation contains lenses of brown dolomite. The dolomite increases in amount to the east, and makes up the entire formation east of the county line.

The sandstone and grit beds contain a characteristic Phosphoria fauna including *Punctospirifer pulcher* (Meek), *Neospirifer pseudocameratus* Girty, and *Linoproductus eucharis* (Girty). Essentially the same fauna is known from the Toquima and Toiyabe Ranges (Ferguson and Muller, 1949, p. 51–52), and near Winnemucca (Edna Mountain formation of Ferguson, Roberts, and Muller, 1952).

PALEOZOIC(?) AND MESOZOIC ROCKS

Permian(?) and Triassic

Excelsior formation

The Excelsior formation was named by Muller and Ferguson (1936, p. 244) from the Excelsior Mountains where it is well exposed about 6 miles southwest of Mina. The formation is widely distributed in the county; the principal exposures are in the southern Pilot Mountains, the eastern Excelsior Mountains and Garfield Hills, the west flank of the Gillis Range, east of Rawhide, and large, irregular roof pendants in the Wassuk Range (fig. 4).

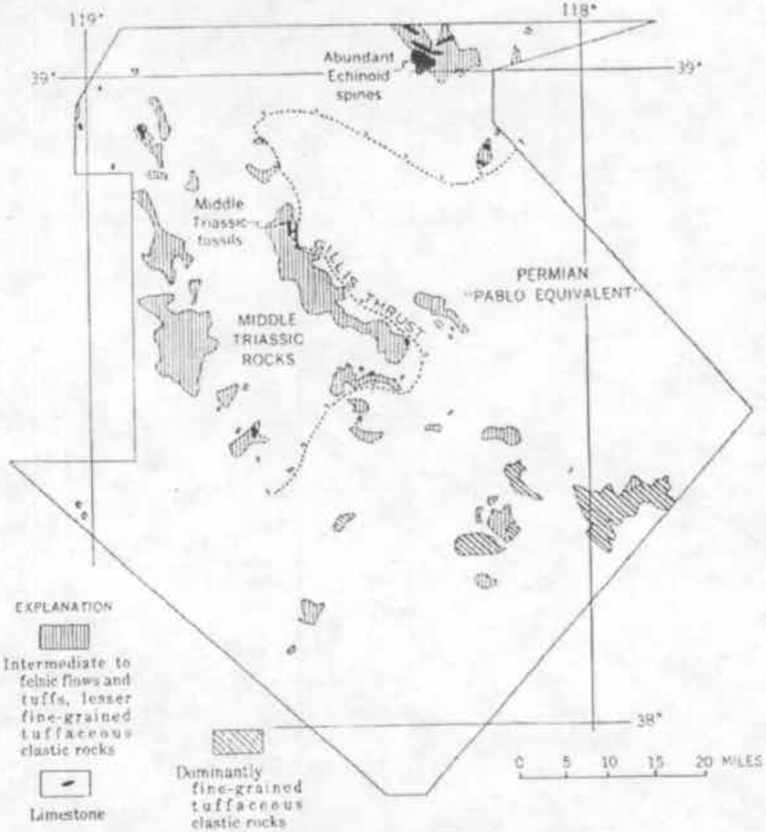


FIGURE 4. Distribution of the Excelsior formation in Mineral County, Nevada, showing generalized lithology, postulated extent of the Gillis thrust, and that part of the formation which may be correlative with the Pablo formation of Permian age (Ferguson and Cathcart, 1954).

The maximum exposed thickness of the Excelsior formation is unknown. The estimated thickness of the formation in the southern part of the Pilot Mountains is in excess of 10,000 feet, where the Excelsior is unconformably overlain by the Jurassic Dunlap formation and the base is not exposed. Just east of the

county, volcanic breccia assumed to be basal Excelsior (?) overlies the Diablo formation unconformably; no other basal relations have been seen.

Lithology. The Excelsior formation is dominantly a volcanic assemblage. It is comprised of flows, tuffs, and breccias ranging in composition from rhyolite to andesite, as well as fine-grained tuffaceous sedimentary rocks. Considerable albitization of the volcanic rocks can be seen, particularly around concentrations of ore deposits. Limestone is present locally in significant amounts and is commonly recrystallized to coarse marble. Original textures are well preserved in places, particularly in the pyroclastic (fig. 5) and fine-grained clastic rocks. In the Wassuk Range

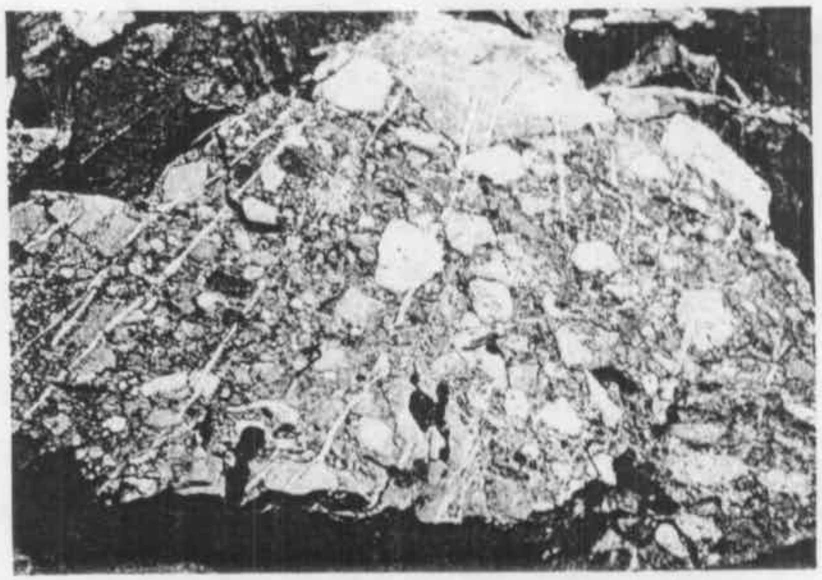


FIGURE 5. Volcanic breccia of the Excelsior formation in Cottonwood Canyon in the Wassuk Range. Note pocketknife near center of boulder for scale.

and around several of the mining districts, however, metamorphism and alteration frequently have destroyed the original features of the rocks. The widespread occurrence of epidote in the Excelsior formation appears to be a useful feature in distinguishing the Excelsior from altered Tertiary volcanic rocks. Most of the rocks are rather dark colored, in shades of gray and green. In cursory field observations the dark color of some of the rhyolitic rocks leads to an over-estimate of the amount of andesite and related rocks.

Petrographic study suggests that neither felsic nor mafic rocks greatly predominate in the Excelsior. To simplify the description of the formation, the Excelsior can be divided lithologically into four types: (1) rhyolitic rocks, including soda rhyolite and quartz latite, (2) intermediate rocks of the rhyodacite and dacite groups, (3) andesitic rocks, and (4) fine-grained tuffaceous clastic rocks.

The rhyolitic rocks include both flows with prominent flow structure and tuffs; some of the tuffs are probably welded tuffs (ignimbrite). Some of the felsic rocks are white to light gray, but others are dark gray and resemble andesite. In the fresher rocks scattered quartz, sodic plagioclase, and potassic feldspar (hereafter referred to as K-feldspar) phenocrysts or fragments are set in a fine-grained groundmass of quartz and feldspar. In some specimens a relict shard texture is remarkably well preserved. Sericitic material is common in the rhyolites, and in the more altered rocks permeates phenocrysts as well as the groundmass. In areas of more intense alteration, particularly in some of the mining districts, rocks of rhyolitic appearance and apparent rhyolitic composition may have been produced from more mafic material by the addition of silica and other materials.

The intermediate rocks include those which have either insufficient dark minerals or plagioclase too sodic to be considered andesitic, as well as those which lack significant amounts of quartz. This category may well include some trachyte and latite. Most of these rocks are dark colored and superficially resemble andesite. Tuffs and flows, or hypabyssal intrusives, are present. Some of the tuffs are possibly welded. In the hypabyssal intrusives plagioclase and less commonly biotite or hornblende phenocrysts are set in a fine-grained matrix of quartz and feldspar. The intermediate rocks are widely distributed in the Excelsior formation, and locally make up a large part of the formation.

The andesitic rocks are dark gray to green and include both tuffs and flows or hypabyssal intrusives. Some specimens contain abundant augite which is in part altered to hornblende, but more commonly hornblende and biotite aggregates are pseudomorphic after the original pyroxene phenocrysts. Andesine to labradorite phenocrysts are locally fresh, but more commonly extensively sericitized. Although the dark color of outcrops suggests that andesitic rocks make up a large proportion of the Excelsior formation in the Wassuk and Gillis Ranges, thin sections indicate that felsic rocks are no less abundant, particularly in the Gillis Range. Some mafic intrusives shown on the geologic map may be genetically related to the andesitic rocks. The mafic intrusives are commonly associated with outcrops of the Excelsior formation, and are similar in composition to some of the andesites.

The fine-grained tuffaceous clastic rocks found locally in various parts of the county are exposed most extensively on the south flank of the Pilot Mountains. These rocks are varicolored, commonly in shades of gray, brown, and red. Most of the rocks are well bedded and contain clastic fragments of coarse to fine sand size. Also common are dense, siliceous rocks that resemble chert. Thin sections of these rocks, however, exhibit a clastic texture with angular silt- to fine-sand-sized quartz fragments scattered in a finer grained mosaic of quartz, feldspar, and mica. In one of the siltstone specimens small, rounded areas suggestive of Radiolaria are visible in thin section. Particles in some of the sandy layers have textures that suggest they are fragments of groundmass material of volcanic rocks. This, plus the association with volcanic layers, suggest that the clastic rocks are in general tuffaceous, although in some places there is no direct evidence of a volcanic parentage.

Fossils and age. The age of the Excelsior formation is based on a single fossil locality in the Gillis Range, where a lens of limestone in the volcanic section has yielded the following forms identified by Muller and Ferguson (1939, p. 1589):

Spiriferina cf. S. *fragilis* (Schlotheim)
S. sp.
Lima cf. *L. lineata* (Schlotheim)
Hornesia aff. *H. socialis* (Schlotheim)
Pleuromya mactroides (Schlotheim) of Goldfuss
Gervilleia (three species)
Pecten aff. *P. tirolicus* (Wittenburg)
Myophoria sp.
Pleurophorus sp.

According to Muller and Ferguson this assemblage suggests an early Middle Triassic age for the Excelsior formation. Although this precise age assignment might be questioned, the fauna is probably at least indicative of the Middle or lower Upper Triassic (N. J. Silberling, oral communication).

Southwest of the Nevada Scheelite mine (pl. 1) echinoid spines are locally abundant in limestone interbeds in the metavolcanic sequence. An abundance of echinoid spines is common in the Middle Triassic and younger Mesozoic rocks of Nevada, but has not been reported in the Early Triassic or older rocks (N. J.

deposits. The Candelaria formation rests with erosional unconformity on the Permian Diablo formation and, where the Diablo has been eroded away entirely, it rests with pronounced angular unconformity on Ordovician rocks.

The formation consists chiefly of greenish-brown shale; sandstone, some of which is tuffaceous; and conglomerate. Locally limestone is present in thin layers and lenses.

At the type locality southeast of Candelaria the basal 150 feet of the formation consists of purplish-gray to black micaceous shale with admixed sandstone and limestone. This is overlain by 75 feet of fossiliferous dark bituminous shale containing some thin limestone beds. The next overlying unit consists of 1,000 feet of green to brown shale, overlain by 1,000 feet of massive brown sandstone (in part tuffaceous?). The uppermost unit consists of 1,000 feet of shale and fine-grained sandstone with minor amounts of limestone. To the east of the type locality, in Esmeralda County, the shale grades into tuffaceous(?) sandstone containing thin lenses of conglomerate in which the fragments are almost entirely chert that has been derived from the underlying Ordovician rocks.

The fossiliferous bituminous shale has yielded an ammonite fauna containing the following species: *Hedenstroemia* (*Clypites*) cf. *H.* (*C.*) *evolvens* Waagen, *Meekoceras* cf. *M. lilangense* Krafft, *M.* cf. *M. tenuistriatum* Krafft, *Proptychites* cf. *P. ammonoides* Waagen, *P.* cf. *P. trilobatus* Waagen, *Grypoceras* cf. *G. brahmanicum* (Griesbach), *Gyrolepsis?* sp. and several species of the pelecypod genus *Claraia*. These forms establish the age of the Candelaria as early Triassic. Details on the significance of these fossils can be found in the paper by Muller and Ferguson (1939, p. 1583–1586) from which the above material was abstracted.

Luning formation

The Luning formation was named by Muller and Ferguson (1936, p. 245) from the small town of Luning; the type locality is designated as the north slope of the Pilot Mountains about 12 miles southeast of Luning.

The Luning formation is widely distributed through the east and central parts of Mineral County, and the best exposures are in the Garfield Hills, Gabbs Valley Range, and the Pilot Mountains (pl. 2). In addition, Luning rocks are abundant at Cedar Mountain, and are present as a chain of outcrops along nearly the entire length of the Gillis Range.

A complete section of the Luning formation is nowhere exposed in Mineral County, but Muller and Ferguson (1939, p. 1595) estimate the total thickness may approach 10,000 feet. The estimated exposed thickness in the Pilot Mountains is about 8,000 feet, in the Garfield Hills 5,000 feet, in the Gabbs Valley Range about 4,000 feet, and at Cedar Mountain the thickness may be about 6,000 feet. The Luning rests unconformably on the Excelsior formation in the Pilot Mountains and the Garfield Hills. Elsewhere the base of the formation is either not exposed, or the Luning is in fault contact with the adjoining formations.

Lithology. The Luning formation consists dominantly of limestone and dolomite with subordinate shale, argillite, and conglomerate; the lithology varies considerably in different ranges. In the type area in the Pilot Mountains the formation is divisible into three members of about equal thickness: a lower limestone; an intermediate member of shale, argillite, and conglomerate; and an upper member of limestone and dolomite. The upper limestone locally contains beds of shale and in the Gabbs Valley Range a massive dolomite overlies the upper limestone. The lower limestone member is exposed only in the Pilot Mountains. As shown in the diagrammatic columnar sections (fig. 6), the upper limestone is a widespread member in which systematic lateral variations in thickness or lithology are not readily apparent from the data available.

Fossils and age. An abundance of fossiliferous material has been collected and described by Muller and Ferguson (1939, p. 1598–1603) from different parts of the Luning section. The collections represent a near-shore pelecypod facies, a coral-reef facies, and an off-shore ammonite facies, all of which contain forms distinctive of the Karnic stage of the European Upper Triassic.

The most common and widespread form in the pelecypod facies is *Alectryonia montis-caprilis;* it is commonly associated with *Myophoria* cf. *M. kefersteini* (Münster), *M.* cf. *M. whateleyae* Buch, and "*Cardita*" sp. Species of *Halobia* and *Trichites* are also present (Muller and Ferguson, 1939, p. 1598).

The coral-reef facies is represented by more than a dozen species of corals and several species of *Spiriferina* and *Terebratula* brachiopods. Details of this facies and its significance are discussed by Muller (1936, p. 202–208).

The ammonite facies includes species of *Gümbelites*, *Carnites*, *Klamathites*, *Juvavites* (*Anatomites*), *Tropites*, and *Styrites* (Muller and Ferguson, 1939, p. 1600–1603).

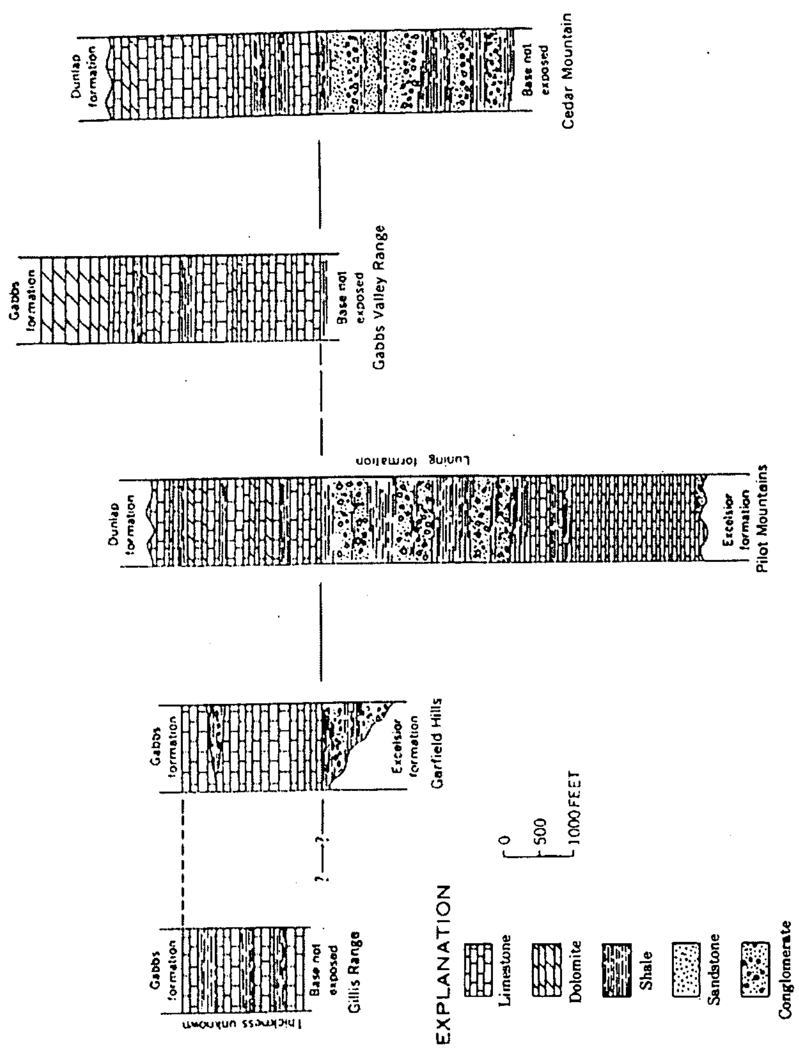


FIGURE 6. Diagrammatic columnar sections of the Luning formation, Mineral County, Nevada.

Triassic and Jurassic

Gabbs and Sunrise formations

The Gabbs formation of Triassic age and the Sunrise formation of Jurassic age are shown as a single unit on the geologic map (pl. 2) because of the close similarity in lithology of the two formations and the difficulty in differentiating these relatively thin units at a scale of 1:250,000.

These two formations were mapped in detail in the New York Canyon area of the Gabbs Valley Range by Muller and Ferguson (1939, pl. 4), where the distinction between the two formations is almost entirely based on paleontology.

The mapping of these units by Muller and Ferguson indicated that in western Nevada the Jurassic is conformable on the Triassic. Prior to this work Jurassic rocks were thought to rest with angular discordance on the Triassic in this part of the country. The historical development of this problem and the paleontologic data that bear on it are discussed by Muller and Ferguson (1939, p. 1613–1616).

The Gabbs formation was named by Muller and Ferguson (1936, p. 248) from the Gabbs Valley Range; the type locality is in New York Canyon about 2,000 feet southeast of Volcano Peak. The Sunrise formation also has its type section in New York Canyon, and the name was derived by Muller and Ferguson (1936, p. 249) from Sunrise Flat at the head of the canyon.

Both formations are best exposed in the Volcano Peak area of the Gabbs Valley Range and are exposed locally in the central and western Garfield Hills and near the north end of the Gillis Range. In addition a small fault block of Sunrise is exposed in the Pilot Mountains east of Mina.

The Gabbs formation is about 400 feet thick at the type locality in New York Canyon; in the same area the Sunrise formation is more than 1,200 feet thick. The partial Sunrise section in the Pilot Mountains may be 600 to 800 feet thick. A continuous conformable sequence exists from the Luning formation through the Gabbs formation and into the Sunrise formation.

Lithology. Both formations consist mainly of interbedded dark-colored shale and limestone in beds a few inches to a few feet thick with some impure limestone, sandy shale, and calcareous sandstone. Several mappable units are differentiated in the type area; the contact between the two formations was established in a 30-foot unfossiliferous interval between the uppermost Triassic forms and the lowermost Jurassic forms (Muller and Ferguson, 1939, p. 1613).

Fossils and age. Both formations contain abundant and well-preserved fossils. Lists of the numerous forms and their age significance are discussed by Muller and Ferguson (1939, p. 1604–1609, 1611–1613). Some representative fossils include, from the Gabbs: *Choristoceras marshi*, *Arcestes gigantogaleatus*, *Pinacoceras metternichi*, and *Sagenites giebeli;* and from the Sunrise: *Eoderoceras*, *Coroniceras*, *Ammonites bisulcatus*, *Euphyllites struckmanni*, and *Psiloceras psilonotum*. The faunal evidence indicates the Gabbs is Upper Triassic (Noric and Rhaetic European stages) and the Sunrise is Lower Jurassic (Hettangian, Sinemurian, and Pliensbachian European stages).

Jurassic

Dunlap formation

The Dunlap formation was named by Muller and Ferguson (1936, p. 250) from Dunlap Canyon in the Pilot Mountains, the designated type section. The formation crops out in a broad belt trending southwest from Cedar Mountain to the west end of the Excelsior Mountains (pl. 2).

At the type locality, the Dunlap formation is about 5,000 feet thick, but this is only a partial section as the upper contact is along a fault against the Luning formation. In the Garfield Hills the Dunlap may be as thick as 3,000 feet. Extreme local variations in thickness of the component units of the formation are common. The Dunlap commonly overlies the Excelsior formation with an angular unconformity of as much as 90°. The contact with the Luning, and locally with the Gabbs, is also one of angular discordance, but generally less than 20°. In the northwestern Garfield Hills and in the southern Gabbs Valley Range the Dunlap overlies an erosional surface on the Sunrise formation, which is only locally a surface of angular discordance.

Lithology. The Dunlap is composed mostly of sandstone, conglomerate, and fanglomerate. This clastic sequence is overlain in some areas by a thick section of volcanic rocks and interbedded tuffaceous sandstone. The conglomerate and fanglomerate that make up most of the upper part of the formation in the Pilot Mountains and the northern Garfield Hills were derived almost entirely from the underlying Luning limestone and dolomite. The lithologic variations are striking (fig. 7) particularly in the coarse conglomerates and volcanic rocks whose distribution is most erratic.

On the maps of Ferguson and Muller (1949) and Ferguson, Muller, and Cathcart (1954), four lithologic types are differentiated in the Dunlap: conglomerate with sandstone, sandstone

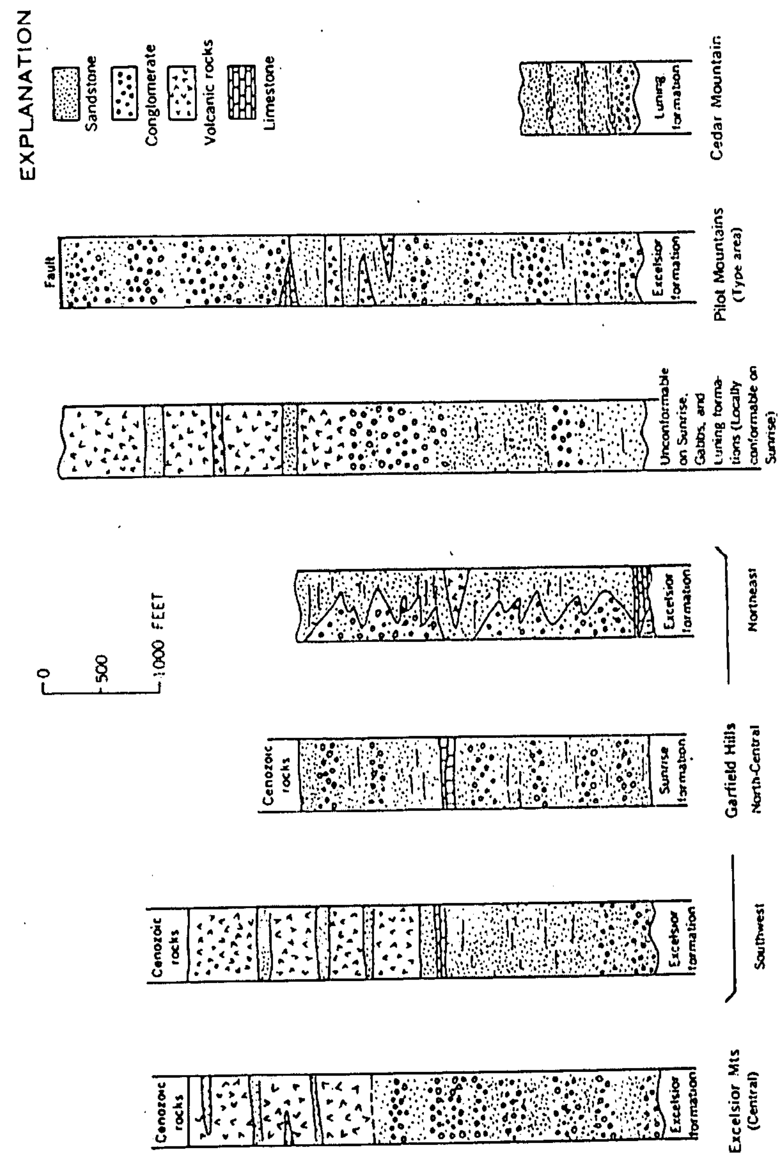


FIGURE 7. Diagrammatic columnar sections of the Dunlap formation, Mineral County, Nevada. (No correlation between columns attempted.)

with conglomerate, volcanic rocks, and calcareous rocks. Correlation of these lithologic units over the county does not seem certain because of changes locally of both lithology and thickness. The diagrammatic sections from the Garfield Hills (fig. 7) exemplify this variation.

In the Gabbs Valley Range, the Excelsior Mountains, and in parts of the Garfield Hills, the clastic rocks are overlain by volcanic rocks, including greenstone, greenstone breccia, felsite, and tuffs with intercalated tuffaceous sandstone. Thinner lenses and layers of volcanic rocks are present in the clastic sequence in some of the other areas.

Fossils and age. Fossils were found by Muller and Ferguson (1939, p. 1621) in only a few of the small limestone and dolomite beds in the Excelsior Mountains and the Garfield Hills. *Harpoceras* sp. and an "*Arietites*"-like ammonite as well as the pelecypod *Plicatostylus gregarius* indicate an Early Jurassic (Pliensbachian and Toarcian) age for the Dunlap.

Diorite and Related Rocks of Uncertain Age

These rocks, chiefly diorite and hornblende gabbro, are widely distributed, particularly in the Wassuk and Gillis Ranges; they underlie about 20 square miles mainly within or adjacent to masses of the Excelsior formation. As a matter of convenience the small areas of peridotite in the Pilot Mountains and serpentine in the Candelaria Hills are discussed here also.

The dioritic rocks are medium- to dark-gray and are composed chiefly of hornblende and plagioclase, with some biotite. In some rocks small amounts of quartz are present, and in others fibrous green amphibole is pseudomorphic after pyroxene.

The common association of the dioritic rocks with the metavolcanic rocks of the Excelsior formation (pl. 2) suggests that they are genetically related. The dioritic rocks, which commonly occur between granitic masses and the Excelsior formation, are probably at least in part the result of contamination of granitic magma by the assimilation of metavolcanic material. The mafic rocks immediately west of Hawthorne at the base of the Wassuk Range, although not as dark as many of the other diorite masses, contain numerous inclusions of rocks of the Excelsior formation and appear to be contaminated granitic rocks. For many of the other areas the origin is less certain, but the distribution of the diorite and the similarity in appearance to contaminated rocks in the Sierra Nevada strongly suggest a hybrid origin. The possibility exists, however, that intrusive rocks of Excelsior age may be present. In particular, those masses completely enclosed in the Excelsior formation, as in the Gillis Range, could be intrusives of Excelsior age.

Peridotite is limited to a single locality along the west front of the Pilot Mountains where a dike less than 100 feet thick extends more than 2 miles. This olivine-bearing dike cuts both aplite and granitic rock (Ferguson and Muller, 1949, p. 30).

Serpentine occurs in small massive dike-like masses just south of Candelaria. Serpentine minerals are widespread in Mineral County and throughout Nevada in small amounts as alteration products of dark minerals, particularly in volcanic rocks, but massive occurrences of serpentine, presumably derived from ultramafic igneous rocks, are rare in the State. The serpentine near Candelaria is the only known massive occurrence in Mineral County, and one of the few known occurrences in Nevada.[4] Antigorite is the dominant serpentine mineral in the Candelaria occurrence but chrysotile and serpophite are also present. Chrysotile veinlets (asbestos) as thick as one-eighth of an inch cut some of the serpentine, and thin dolomite veinlets are also locally present. There are no obvious mineral outlines to indicate the original mineralogy of the serpentine, but one specimen contains a network of fibrous antigorite in which are set numerous small, rounded cores of the low birefringent, massive material known as serpophite; this texture is indicative of an olivine-rich parent rock. Abundant stringers and scattered grains of magnetite and hematite in this rock are further suggestive that the parent rock was an ultramafic intrusive rock. Chromite is also present in the serpentine. Magnetite is abundant in the serpentine; it is more compatible with an ultramafic parent than with a carbonate one, particularly since iron-rich carbonate rocks, from which the abundant magnetite would be formed in the process of serpentinization, are unknown in this area. Dolomitic rocks locally are peripheral to the serpentine and are probably an alteration product of the serpentine. The serpentines are, therefore, probably altered ultramafic intrusive masses. Their age is unknown, but they intrude the Candelaria formation of Early Triassic age.

Cretaceous(?)

Granitic rocks

Medium- to coarse-grained granitic rocks are widely distributed in Mineral County. They consist chiefly of quartz monzonite but range in composition from granodiorite to albite granite. Along the western margin of the county, granitic rocks underlie

[4]Serpentine is present in the north end of the Hot Springs Range in Humboldt County (R. Willden, oral communication, 1957).

more than half of the Wassuk Range; to the east the granitic rock masses are smaller and more scattered as distance from the Wassuk Range increases. Continuity of the large granitic masses in the western part of the county with the Sierra Nevada batholith complex to the west is strongly suggested by the numerous granitic masses protruding through the Cenozoic cover separating the two areas, although surface outcrops of granitic rocks are not continuous (fig. 8). The close similarity of the texture

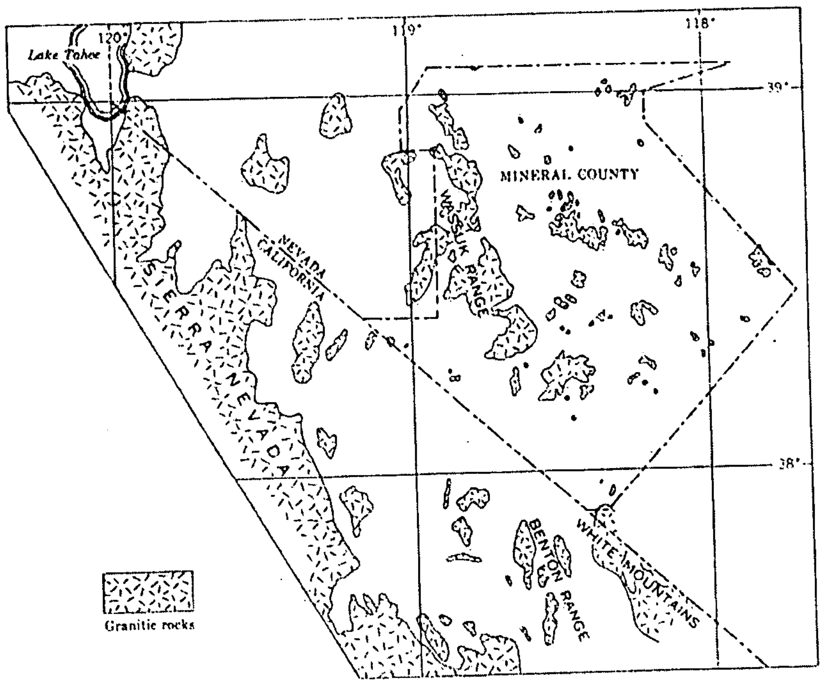


FIGURE 8. Spatial relationship of granitic rocks in Mineral County to those of the Sierra Nevada.

and composition of many of the granitic rocks in Mineral County to those in the Sierra Nevada also suggests that the granitic rocks of both areas are parts of the same batholithic complex.

The granitic masses range in size from dikes, sills, and small stocks to bodies of batholithic proportions in the Wassuk Range. Many of the stocks are relatively homogeneous and probably are simple intrusives, but the larger masses are generally composite intrusives. Cross-cutting relations were observed by Cathcart and Foshag in the Wassuk Range (Ferguson, Muller, and

Cathcart, 1954), and several distinct rock types were observed in the Wassuk Range by the writer.

Generally areas of granitic rock are easily identified in the field, even from a considerable distance, because they weather to distinctive bouldery and hummocky surfaces. This feature is also readily apparent on the air photos for many of the masses. It is necessary to observe one caution with this method of identification, however; some of the felsic welded tuffs form a similar weathered slope.

Method of study. Considerable reliance was placed on hand specimens in the petrographic study because of insufficient time in which to obtain thin sections. The thin section analysis of the granitic rocks was limited almost entirely to the study of sections from specimens collected during the reconnaissance survey of Ferguson and Cathcart in the 1920's. The problem of obtaining quantitative data on these rocks without studying thin sections or chemical analyses was partly solved by making modal analyses of sawed slabs prepared from representative specimens collected by the writer and Kleinhampl. The slabs were etched with hydrofluoric acid, then stained with sodium cobaltinitrite to distinguish the K-feldspar, and then modally analyzed in the manner described by Jackson and Ross (1956, p. 648–651). A modification of the original method, yielding improved results, was the immersion of the sawed surface in hydrofluoric acid for about 10 seconds rather than fuming the surface above the acid for 3 minutes as originally suggested.

To obtain information on the composition of the plagioclase, X-ray diffraction patterns were made from powdered plagioclase of selected specimens. The plagioclase is readily separable from the other constituents in these medium- to coarse-grained rocks by crushing a small piece of the rock to fragments somewhat smaller than the average grain size of the rock. The fragments are then immersed in hydrofluoric acid, stained with sodium cobaltinitrite and the white plagioclase grains are separated from the clear quartz and yellow stained K-feldspar grains with the aid of a binocular microscope.

The above-described techniques provide much data on the mineralogic composition and texture of the rocks and also give the average anorthite molecule content of the plagioclase of a specimen. With these methods, information can be acquired quickly; they seem ideally suited for the study of medium- to coarse-grained granitic rocks in reconnaissance studies when time is limited and thin sections and chemical analyses are not available.

Petrography. In outcrop the granitic rocks are generally various light shades of gray, although yellowish to pale-red colors are common locally. Fresh specimens generally consist of white to light-gray feldspar, clear quartz, and nearly black hornblende and biotite. In some masses the K-feldspar is a distinctive orange pink. The yellow and orange colors of weathered rocks are chiefly the result of the formation of iron oxide from the chemical weathering of the dark minerals.

Typically the granitic rocks are medium-grained (2 to 5 mm) and equigranular, but coarse-grained varieties are abundant locally. The coarser rocks are commonly seriate with the largest crystals, generally K-feldspar, as large as 15 mm. Many of the granitic rocks have the typical granitic texture (hypautomorphic granular) and closely resemble the rocks of the Sierra Nevada batholithic complex. The plagioclase and dark minerals are generally well formed and quartz and K-feldspar are interstitial, particularly in those rocks that contain an appreciable amount of dark minerals. In the more felsic rocks that are composed dominantly of feldspar and quartz, however, the grains are typically anhedral. One notable exception to the typical granitic texture is in the eastern part of the county, particularly in the Cedar Mountains, where there are several small masses of porphyry which consist of from 30 to 50 percent of medium-grained quartz and feldspar phenocrysts set in a fine-grained matrix. In the White Mountains some of the granitic rocks are notably gneissic.

The study of thin sections, from the survey of Ferguson and Cathcart in the 1920's, and of hand specimens collected in 1956, shows that for summary purposes the granitic rocks can be divided into three categories (1) quartz monzonite and granodiorite similar to the Sierra Nevada granitic rocks, (2) albite granite and related rocks commonly low in quartz, and (3) quartz monzonite porphyry.

Modal analyses of representative specimens from most of the major intrusive masses show that quartz monzonite and granodiorite are the most abundant intrusive rocks. The locations of representative specimens are plotted on figure 9; the modal data are listed on table 3 and summarized in figure 10. This group of intrusive rocks, which has affinities with the intrusive rocks of the Sierra Nevada, appears to be dominantly quartz monzonite on the basis of the modal data. The dark minerals (not differentiated

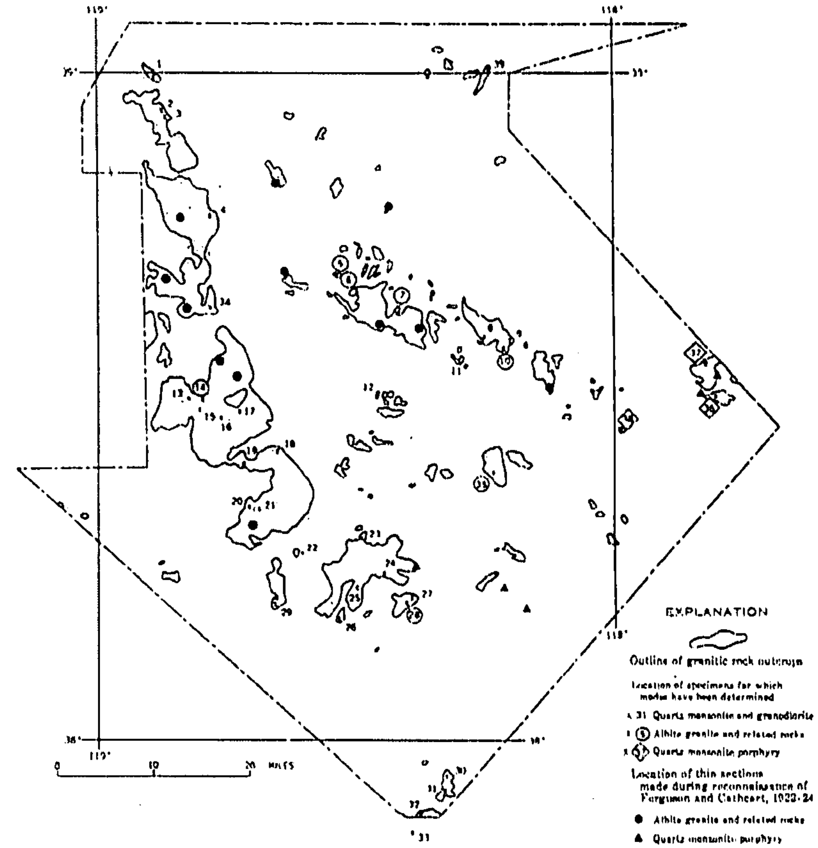


FIGURE 9. Index map showing areas from which samples of granitic rocks were taken.

in most of the modal analyses) consist of both hornblende and biotite in the darker rocks, but biotite is greatly predominant or is the only dark mineral in most of the quartz monzonites.

The presence of albite granite and related rocks became known through thin section study; they were not recognized as such during the field work and therefore their relative abundance is not known. Available specimens indicate that albitic rocks are most abundant in the Gillis Range (fig. 9). At some localities, particularly in the Wassuk Range, albitic rocks are closely associated with granitic rocks typical of the Sierra Nevada. Several thin sections made from albitic rocks collected during the reconnaissance of the 1920's were examined. These localities from which they were taken are shown on figure 9. These sections are

TABLE 3. Modes of granitic rocks, Mineral County, Nevada

Spec. No.*	Plagioclase percent	An†	K-feldspar percent	Quartz percent	Dark minerals percent		Total point counts
1	62	20	14	19	5		1797
2	32	21	34	31	3		1339
3	31	24	33	31	5		2536
4	41	29	17	32	10		1004
5	27	10	54	15	4		1314
6	41	14	43	14	2		1361
7	35	13	48	14	3		1761
8	29	28	38	25	8		1038
9	33	30	45	15	7		1577
10*	27	‡	41	26	6		1166
10†	17	10	61	18	4		1357
11	32	25	35	28	5		1878
12	43	30	25	18	14		1459
13	35	27	31	22	12		1843
14	31	10	31	34	4		1292
15	38	20	29	29	4		1289
16	52	28	15	23	10		1544
17	29	18	38	28	5		813
18	28	30	20	32	10		1325
19	38	22	29	30	3		1203
20	47	30	21	21	11		922
21	54	31	14	21	11		1362
22	51	30	30	5	14		1618
23	23	20	47	27	3		2032
24	41	24	27	25	7		1241
25	41	31	20	22	17		1233
26	33	20	33	28	6		2156
27	24	‡	35	40	1		1097
28	24	6	40	35	1		1639
29	35	21	34	28	3		1880
30	30	4	39	23	8		1114
31	38	32	24	21	17		1541
32	38	20	35	24	3		1225
33	44	22	27	26	3		1778
					Biotite	Hornblende	
34	45	27	13	32	9	.	700
35	26	3	46	28	tr.	tr.	682
36	34	31	35	24	2	5	587
37	39	33	31	24	4	2	634
38	60	36	24	11	1	4	489
39	56	27	15	17	7	5	578
Average	38	..	33	25	7		

*Specimens located on figure 12. Specimens 1 through 33 are slabs, 34 through 39 are thin sections.

†Average anorthite content of plagioclase, in percent, determined by X-ray powder diffraction methods; results based on curves of Smith and Yoder (1956). Supplementary checks of index of refraction of cleavage flakes and the extinction angle perpendicular to 001 and 010 suggest the X-ray determinations are correct or within small limits of error for these rocks, but without confirmatory chemical data the limits of error are unknown.

‡Not determined.

characterized by both chessboard and normal polysynthetically twinned albite, chloritization of dark minerals, and albite which is commonly extremely "dusty" with sericitic material. The hand specimens that contain albite (or sodic oligoclase), particularly those from the Gillis Range, are low in dark minerals, and most are low in quartz. A replacement origin of the albite granite by the albitization of other granitic rocks is suggested because of (1) chessboard type of twinning of the albite, (2) extensive alteration of both hornblende and biotite to chlorite and epidote, and (3) the close association of the albitic rocks with quartz monzonite and granodiorite.

The quartz monzonite porphyry is not volumetrically important, but because it is locally abundant and texturally distinctive from the other granitic rocks it is distinguished on the location

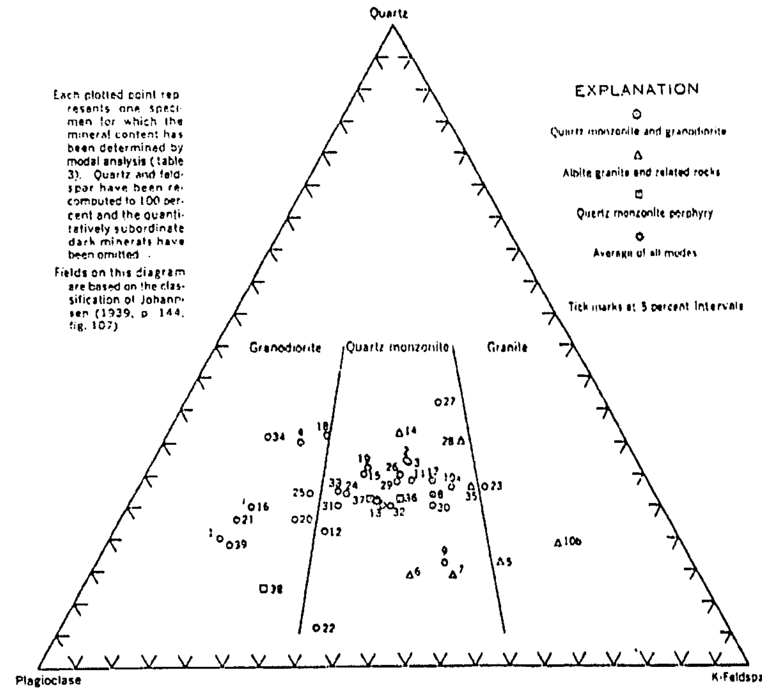


FIGURE 10. Summary of modal data on granitic rocks in Mineral County, Nevada.

map (fig. 9). The texture of this rock, which has already been briefly described, is particularly distinctive on a stained sawed surface and shows a fine-grained interstitial groundmass in which are set euhedral to subhedral phenocrysts as large as 10 mm, but more typically 3 to 5 mm, long. The phenocrysts are dominantly zoned plagioclase (andesine to oligoclase), K-feldspar, and quartz, with lesser biotite and hornblende. The quartz phenocrysts are particularly distinctive because of their rounded cross-sectional shape. The crystals were originally hexagonal or square in outline, but were rounded by resorption. This quartz habit, typical of high temperature (beta) quartz, and the fine-grained groundmass suggest these rocks crystallized more rapidly than the typical granitic rocks, probably because they are smaller masses or were intruded to shallower depths. Mineralogically, these rocks are similar to the rocks with granitic texture, and probably differ only in cooling history.

Age. The granitic rocks intrude the Dunlap formation of Early Jurassic age and their eroded surfaces are overlain by mid-Tertiary deposits. No data from within the county are known at this time to date more precisely the granitic rocks within this long interval. In the Sierra Nevada and in central Nevada, however, recent studies of granitic rocks based on radiometric measurements of zircon (Larsen, Keevil, and Harrison, 1952) and potassium-bearing minerals (Evernden, Curtis, and Lipson, 1957) have resulted in the age determinations shown on table 4.

The age determination studies of the Sierra Nevada granitic rocks in California indicate a Cretaceous age, and those of the Nevada localities indicate an Eocene age. Considering the close lithologic relationship between the large batholithic masses in the western part of the county and the Sierra Nevada, the bulk of the granitic rocks of Mineral County is probably best considered to be Cretaceous(?) in age. Some of the granitic rocks in the eastern part of the county may be younger and more closely related to the granitic rocks farther east in Nevada that are currently dated as Eocene, but in this report, for the sake of simplicity, all the granitic rocks of the county will be considered to be Cretaceous(?).[5]

CENOZOIC ROCKS

Tertiary

In Mineral County the rocks of Tertiary age have been divided into three units. The oldest is a group of volcanic rocks, which generally are altered and contain some mineral deposits. Overlying these rocks, particularly in the eastern part of the county, is the Esmeralda formation, which is made up of lacustrine and associated continental beds. In turn the Esmeralda formation is overlain by a younger group of generally unaltered volcanic rocks. This distinction has been extrapolated to other parts of the county where the Esmeralda formation is not present; areas of distinctly altered volcanic rocks and most volcanic areas with significant mineral deposits are assumed to be pre-Esmeralda in age.

The younger, post-Esmeralda volcanic rocks can be divided into two general lithologic types. One type consists of light-colored felsic rocks, chiefly rhyolite and quartz latite, and the other is made up of darker colored intermediate rocks that range

[5]After the manuscript was completed, an age of 40 ± 10 million years (Eocene) was determined by the U. S. Geological Survey by the lead-alpha method from zircon from the granitic mass about 5 miles southeast of the site of Simon on Cedar Mountain. This result suggests that at least some of the granitic rocks in Mineral County are younger than the Sierra Nevada intrusives.

TABLE 4. Ages of some granitic rocks from Nevada and California

	Age (in millions of years)	Method	Distance from Mineral County	Area	Source
Cretaceous	100	zircon	50 miles; S.	Bishop district, California	P. C. Bateman (oral communication, 1955)
	84 to 96	potassium-argon	55 miles; SW.	Yosemite, California	Evernden, Curtis, and Lipson (1957)
Eocene	42	zircon	70 miles; NE.	Austin, Nevada	R. J. Roberts (oral communication, 1956)
	45	zircon	120 miles; NE.	Antler Peak quadrangle, Nevada	R. J. Roberts (oral communication, 1956)

in composition from rhyodacite to andesite and possibly basalt. Hereafter, in order to emphasize their range of composition, the terms felsic and intermediate will be used in referring to these groups of rocks, in preference to the more restrictive terms rhyolite and andesite commonly used. This lithologic distinction has a stratigraphic value also, because the intermediate rocks commonly overlie the felsic rocks. This same relationship has been found east of the county in the Coaldale quadrangle (Ferguson, Muller, and Cathcart, 1953), where the Gilbert andesite overlies the Oddie rhyolite; to the southwest where Gilbert (1941, p. 802) records andesitic rocks overlying rhyolitic rocks; and to the west in the Sweetwater Range where similar groups of rocks in the same relative positions were found by W. H. Swayne (personal communication cited in Gilbert, 1941, p. 801). The relationship of felsic volcanic rocks overlain by intermediate volcanic rocks is therefore widespread in this general area.

However, this relationship is undoubtedly an oversimplification of the volcanic history of the county; in the northern part more than one intermediate sequence is probably present, and in some other areas the relationship between the intermediate and felsic rocks is uncertain. Further evidence that the Tertiary volcanic history is more complex than the relatively simple picture presented in this report is afforded in the Aldrich Station area in the western part of the county. Here, one of the few places in the county where the Tertiary rocks have been studied in detail, Axelrod (1956, p. 19–87) reports andesitic flows and tuffs which underlie, are interbedded with, and overlie a Miocene and Pliocene sedimentary section. An added complication to the Tertiary section is the Toiyabe quartz latite, which east of the county overlies the Gilbert andesite (Ferguson and Cathcart, 1954). The Toiyabe quartz latite is lithologically similar to the crystal tuffs that make up the bulk of the felsic rocks of the county. Thus it is probable that the felsic rock unit used on the geologic map of Mineral County (pl. 2) includes rocks that overlie as well as underlie the andesitic rocks. These doubtful relationships and the equivocal lithologic comparisons seem to preclude extending throughout Mineral County at this time the formational names used for the volcanic units in the Coaldale quadrangle.

The petrography of the Tertiary and Quaternary volcanic rocks is based on a large number of thin sections made following the earlier reconnaissance of Ferguson and Cathcart. Data on the chemical composition of these rocks consist chiefly of seven chemical analyses that were made of representative post-Esmeralda volcanic rocks (table 5). Additional compositional data for

some of the post-Esmeralda specimens for which neither thin sections nor analyses had been made were obtained by index of refraction studies. For these studies the index of refraction of glass beads fused from a powdered sample of the volcanic rock is used to determine the approximate silica content of the rock in the manner described by Mathews (1951, p. 92–101). To establish the relationship between the silica and the index of refraction of the glass, the index is plotted against the silica content of the chemically analyzed specimens. These points (fig. 11) establish a curve from which the silica content of a rock can be estimated from the index of refraction. Figure 11 also compares the curve obtained for the Mineral County volcanic rocks with similar curves from volcanic suites in the Sierra Nevada, 30 to 50 miles to the west. Figure 12 shows the range of index of refraction of widely separated, representative samples of various mapped volcanic units, and is intended chiefly to show the calculated silica range in these units. Also shown on figure 12 are the silica contents of average volcanic rocks of Nockolds (1954, p. 1007–1032) for comparison with the glass bead samples.

Pre-Esmeralda volcanic rocks

Volcanic rocks which have been grouped together as pre-Esmeralda are found at Cedar Mountain, near Rawhide, at the north end of the Gillis Range, near Aurora, and northwest of Aurora near the county line (pl. 2). Except at Cedar Mountain, where these volcanic rocks definitely underlie the Esmeralda formation, the designation of the rocks as pre-Esmeralda is subject to some doubt. Alteration and mineralization, which characterize the pre-Esmeralda rocks of Cedar Mountain, are used as criteria for placing the Rawhide and Aurora occurrences in the pre-Esmeralda group. Northwest of Aurora, altered volcanic rocks underlie fresh intermediate rocks, and so may be correlative with the other altered volcanic rocks in the county. The rocks at the north end of the Gillis Range are with least certainty correlative with the pre-Esmeralda section. These rocks probably underlie the felsic sequence, but this is not certain; furthermore they are not as noticeably altered as at the other localities.

A thickness of about 3,000 feet of pre-Esmeralda rocks is exposed just east of the county (Ferguson, Muller, and Cathcart, 1953). Within the county less than 1,000 feet of volcanic rocks (Knopf, 1922, p. 367–369) are exposed in an incomplete section near the Simon mine at Cedar Mountain; it is not known if this

TABLE 5. Chemical analyses, norms, Niggli numbers, and Rittmann numbers of Cenozoic volcanic rocks, Mineral County, Nevada

Specimen*	1	2	3	4		5	6	7
SiO_2	51.8	59.7	60.2	59.6	†64.5	71.3	72.4	74.5
Al_2O_3	16.8	16.8	16.7	16.6	18	14.7	13.9	14
Fe_2O_3	3.3	4.9	2.3	2.9	3.1	2.2	1.8	0.84
FeO	4.6	1.2	3.1	0.83	0.9	0.37	0.20	0.08
MgO	6.4	2.3	2.8	2.2	2.4	0.70	0.59	0.22
CaO	7.3	5.4	4.8	2.8	3	2.3	1.5	1.2
Na_2O	3.3	4	3.8	2.5	2.7	3	3.1	3.8
K_2O	3.4	2.9	3.8	4	4.3	4.4	4.5	4.9
TiO_2	1.4	0.82	0.92	0.72	0.8	0.31	0.28	0.12
P_2O_5	0.90	0.32	0.46	0.10	0.1	0.01	0.01	0.00
MnO	0.14	0.08	0.10	0.10	0.1	0.04	0.02	0.06
H_2O	0.39	1.2	0.66	7.6	....	0.98	1.8	0.37
CO_2	0.20	0.09	0.11	0.06	0.06	0.08	0.05	0.06
NORMS								
Q	....	13.38	10.98		22.02	31.1	33.6	30.8
or	20.02	17.24	22.24		25.58	26.1	26.7	28.9
ab	27.77	34.06	31.96		23.06	25.2	26.2	32
an	21.13 An43	19.18 An36	17.51 An35		15.01 An40	11.4 An31	7.5 An22	5.8 An15
diop	5.42	4.21	1.66		-------	....	....	....
hyp	13.4	....	8.28		-------	....	....	....
Mg metasil	....	3.10	....		6	1.7	1.5	0.5
ol	1.7	-------	-------		-------	-------	-------	-------
mgt	4.87	1.62	3.25		0.7	-------	-------	-------
hm	....	3.84	....		2.56	1.9	1.8	0.8
ilm	2.74	1.52	1.67		1.52	0.6	0.5	-------
ap	2.02	-------	1.34		-------	-------	-------	-------
cor	....	-------	-------		3.26	0.8	1.1	2.4
NIGGLI NUMBERS								
si	133	202	204		250	359	402	434
al	25.5	33	33		41	43.5	45	48
fm	41	28	29		26	15.5	13.5	5
c	20	19.5	17		12	12.5	9	7
alk	13.5	19.5	21		21	28.5	32.5	40
qz	—23	20	20		62	139	166	174
RITTMANN NUMBERS								
k	0.4	0.33	0.4		0.53	0.51	0.49	0.46
an	0.29	0.26	0.22		0.33	0.19	0.16	0.09
p	51.5	57	55.5		66.5	63.5	62	59
Rittmann rock name	(olivine-andesine trachybasalt)	(rhyodacite)	‡(dark quartz latite)		(quartz latite)	(quartz latite)	(rhyolite)	(rhyolite)

*Sample number, location, and map symbol (pl. 2).
†Recalculated to 100 percent without H_2O.
‡Very near latite boundary.

Analysts: P. L. D. Elmore, S. D. Botts, K. E. White: U. S. Geological Survey.

1. (RM 5-37-5) T. 2 N., R. 33 E. Southwest of Basalt (QTm, mafic volcanic rocks).
2. (RM 4709-1) T. 5 N., R. 34 E. Northeast of Belleville (Tvi, intermediate volcanic rocks).
3. (RM 4703-5) T. 5 N., R. 30 E. East front Wassuk Range (QTm, mafic volcanic rocks).
4. (RM 4816-5) T. 4 N., R. 30 E. South end Wassuk Range (Tvi, intermediate volcanic rocks).
5. (RM 6864-1) T. 2 N., R. 33 E. North of Basalt (Tvf, felsic volcanic rocks).
6. (RM 11922-1) Cedar Mountain (Tvf, felsic volcanic rocks).
7. (RM 2702-16) T. 8 N., R. 32 E. East of Hawthorne (Tvf, felsic volcanic rocks).

is the maximum exposed thickness in the county. The pre-Esmeralda rocks lie unconformably on Mesozoic rocks at Cedar Mountain, and the basal contact is not exposed elsewhere in the county.

Lithology. A considerable variety of rocks in shades of white, gray, yellow, green, brown, and red and ranging in composition from rhyolite to andesite make up the pre-Esmeralda sequence.

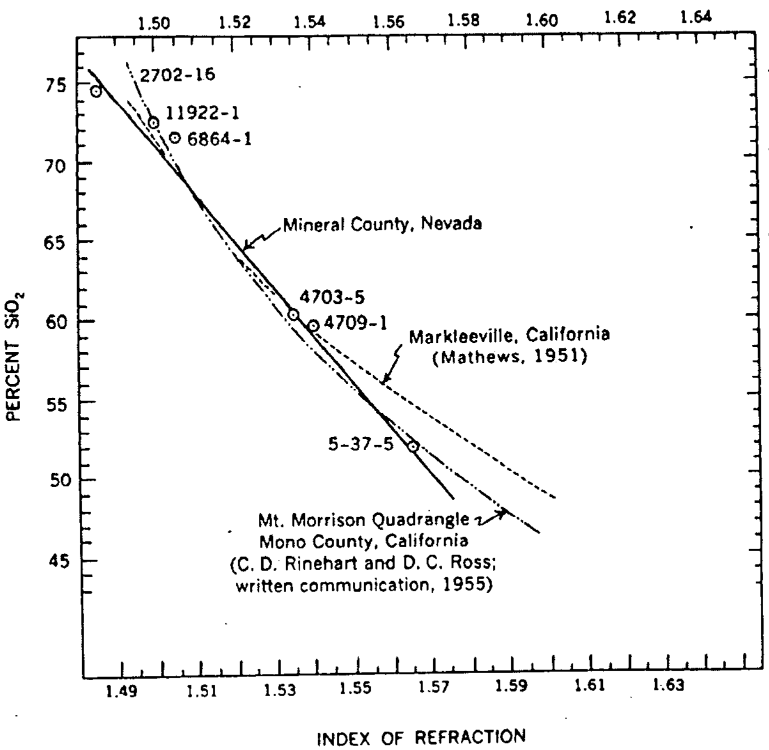


FIGURE 11. Diagram showing relation between SiO_2 content and index of refraction of fused glass beads from volcanic rocks. Numbers refer to chemically analyzed specimens listed on Table 5.

Because little thin section study has been done on these rocks and no chemical analyses are available, it is possible that some of the rocks here referred to as andesite are less mafic. No attempt has been made to correlate the rock types from one pre-Esmeralda occurrence to another because variations within and between areas are considerable, and alteration and mineralization have added further complications.

At Cedar Mountain several rock types have been distinguished

by Knopf (1922, p. 367–369). He records a section at the Simon mine, from base to top, of andesite, keratophyre, pyroxene andesite, and dacite tuff. The andesite is a dull grayish-green porphyritic rock with small tabular sodic labradorite phenocrysts; hornblende and minor augite were also identified, and the groundmass contains microlites of feldspar. The overlying keratophyre is a white dense rock with inconspicuous albite phenocrysts;

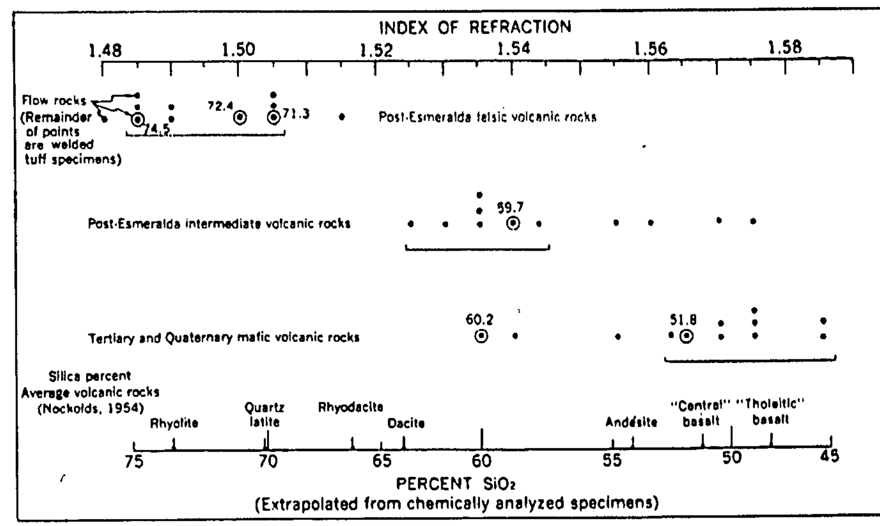


FIGURE 12. Index of refraction of fused glass beads from volcanic rocks. (Circled dots show SiO_2 content, in percent, of chemically analyzed specimens.)

locally this rock is spherulitic, particularly near the base, and biotite phenocrysts, commonly bleached, are sparsely scattered throughout. The pyroxene andesite is purplish, where fresh, and has more numerous and larger plagioclase phenocrysts than the basal andesite; it also contains abundant small grains of dark minerals. The dacite tuff is white and consists of fragments of labradorite, quartz, biotite, and less common hornblende, set in a matrix of glass shards.

At the Olympic mine (commonly abbreviated OMCO, for Olympic Mining Co.), about 4 miles north of the Simon mine, the section is made up of light-colored felsic rocks, probably rhyolite and quartz latite. Some of the rocks contain prominent crystals of quartz and feldspar and resemble crystal tuffs. Some of the rocks that lack visible quartz and have been provisionally referred to as trachyte by Knopf (1922, p. 380), could also be rhyolitic, as visible quartz is commonly lacking in rhyolitic rocks.

The probable pre-Esmeralda rocks near Rawhide are generally altered, and the mines of the district are located in these altered rocks. Most of the meager data concerning these rocks come from the field notes F. C. Schrader made during several trips to the district from 1911 to 1920. Schrader noted several rock types, which he referred to in the field as rhyolite, latite, dacite, and andesite, and these rocks were found in various shades of gray, brown, yellow, and green. Because no thin section or chemical data are available, the names applied to them by Schrader may not be precise, but it seems fairly certain that a considerable variety of lithologic types are present at Rawhide. Rhyolitic to dacitic varieties are most common and andesites are locally abundant, judging from Schrader's notes and from a brief visit the writer made to the district. It should be noted here that cursory observation of volcanic rocks in areas of considerable alteration may result in erroneous conclusions concerning the abundance of various rock types. The same rock type may be given different names because of differences in the intensity or kind of alteration. Also clay alteration, silicification, and bleaching may lead to overemphasis of the light-colored rhyolitic rocks.

At Aurora the country rock of the more important mines is an altered volcanic rock, which has been mapped as part of the pre-Esmeralda group. Hill (1915, p. 145) describes the most common rock of the district as a biotite-quartz latite. It is a greenish-gray rock with phenocrysts of andesine, biotite, and pyroxene (?) set in a groundmass of andesine, abundant interstitial quartz, and K-feldspar. Intrusive into these rocks is a light-green, fine-grained, porphyritic andesite made up of phenocrysts of andesine and augite set in a groundmass of the same minerals. The andesite is probably closely related in age to the quartz latite. Both rock types are altered and cut by veins of calcite and quartz.

Northwest of Aurora near the county line altered rocks of unknown but probably intermediate composition are exposed. The fresher specimens commonly have abundant, small, plagioclase phenocrysts set in a rather dark-colored dense groundmass; locally hornblende phenocrysts are dominant. Tuffaceous sediments are locally associated with these rocks. Much of the rock is altered, in places to a spongy, massive, red-stained siliceous rock. Some slopes of bleached and altered rock are outlined by an absence of the normally common sagebrush and piñon pine and the presence of scattered Jeffrey pines, normally absent in this area. The Jeffrey pines are probably present because of an acid soil which has resulted from the breaking down of pyrite in these rocks during alteration.

Esmeralda formation

Late Tertiary lacustrine and continental sedimentary deposits are widespread throughout western Nevada. In Mineral County such deposits have previously been referred to the Esmeralda formation, first described by Turner (1900, p. 197–208) from the type locality at the north end of the Silver Peak Range in Esmeralda County. Recent work by Axelrod (1956, p. 8), however, has shown that:

> ". . . the late Tertiary continental basins in this area [western Basin and Range province] were relatively local in extent. The common practice of indiscriminately applying such formational names as Esmeralda, Truckee, and Humboldt over wide areas in Nevada finds little support in field evidence. Each basin appears to record a different history, not only in terms of the type of rock represented, but also in a structural sense. Only by interpreting these rocks in detail can we hope to understand in some small measure the complex Tertiary geologic history of this region."

In the present report, however, the name Esmeralda formation is retained for all the late Tertiary sedimentary rocks because of the need for a term to include both the rocks studied in detail and those mapped only in reconnaissance fashion. Beds correlated by Buwalda (1914) with the Esmeralda formation in the Silver Peak Range are exposed over a large area in Stewart Valley, between Cedar Mountain and the Gabbs Valley Range. In Coal Valley on the west flank of the Wassuk Range, a thick section of the Esmeralda formation has been studied in detail by Axelrod (1956, p. 19–87). He has subdivided the section here into three units, which he calls the Aldrich Station, Coal Valley, and Morgan Ranch formations. Other exposures in the county of late Tertiary sedimentary rocks of uncertain formational designation are also included here.

The thickest section of the Esmeralda is in the Coal Valley area where Axelrod (1956, p. 23) records a maximum thickness of about 8,000 feet. This is comprised of, from base to top: (1) the Aldrich Station unit, 4,000 feet; (2) the Coal Valley unit, 3,300 feet; and (3) the Morgan Ranch unit, 700 feet. In Stewart Valley, Buwalda (1914, p. 347) estimated the maximum thickness of the Esmeralda formation at about 1,000 feet.

Lithology. The Esmeralda formation is made up to lacustrine and terrestrial deposits of a considerable variety, as well as rhyolitic pyroclastic rocks and andesitic flow rocks. In addition, in some areas intrusive and extrusive rhyolitic rocks may be Esmeralda in age.

In the Coal Valley area[6] the basal Aldrich Station formation of Axelrod is a fluvio-lacustrine deposit of siliceous shale, punky diatomaceous shale, siltstone, sandstone, rhyolite tuff, pumice, and volcanic pebble conglomerate. The overlying Coal Valley formation of Axelrod is also of fluvio-lacustrine origin and consists of fine-grained lake deposits, sandstone, conglomerate, and sedimentary breccia. Interbedded in this formation are hornblende-bearing andesitic rocks. The overlying Morgan Ranch formation of Axelrod (exposed only west of the county line) is dominantly a fanglomerate composed of granitic material, but locally contains lenses of dominantly volcanic and metamorphic rock fragments. Detailed descriptions of these formations and a planimetric geologic map of the Coal Valley area (scale 1:18,000) are found in the Axelrod report (1956, p. 23–35).

In the Stewart Valley area the strata are dominantly white to light-gray, thin-bedded, lacustrine sandstone, shale, calcareous shale, and tuff. Fanglomerate, conglomerate, and coarse sandstone are common near the ranges, and these coarser beds grade into finer sediments in the center of the valley. Pyroclastic material, grading from fine-grained tuff to coarse rhyolitic breccia is the most abundant rock south of this area near the Pilot Mountains.

Both the Aldrich Station and Coal Valley formations of Axelrod contain thin lignitic coal seams. Diatomaceous beds are common in the Basalt area and are exploited commercially east of the county line.

Fossils, age, and correlation. Fossils in the age range of late Miocene to early Pliocene have been collected from the fluviatile-lacustrine deposits in Stewart Valley, Coal Valley, and south of Hawthorne. In Stewart Valley a collection of mammals, fish, and mollusks, which was made by Buwalda (1914, p. 350–352), was considered to be Miocene in age. In Coal Valley, collections of mammals and plants (Stirton, 1940, p. 634; Axelrod, 1956, p. 55–61) are dated as late Miocene to early middle Pliocene in age. In addition Pliocene mammal remains have been found south of Hawthorne (Van Houten, 1956, p. 2085). The Esmeralda is therefore considered to be Miocene and Pliocene in age and occupies a stratigraphic position common to several other fluvio-lacustrine sequences in Nevada and eastern California (Van Houten, 1956, p. 2814, 2816).

[6]Mostly in Lyon County west of Aldrich Station.

Post-Esmeralda felsic volcanic rocks

Post-Esmeralda felsic volcanic rocks, chiefly rhyolite and quartz latite, are widely distributed over the county with the largest areas of outcrop in the Gabbs Valley and Gillis Ranges, and near Miller Mountain (pl. 2). At the north end of Cedar Mountain, the quartz latite previously referred to as pre-Esmeralda by Knopf (1922, p. 369) is post-Esmeralda and lithologically similar to this felsic sequence.

The maximum exposed thickness in the county is probably at Miller Mountain or in the Gabbs Valley Range where the thickness may approach 2,000 feet. The felsic sequence overlies the Esmeralda formation conformably near Basalt (Ferguson, Muller, and Cathcart, 1954) but elsewhere in the county either the basal relations are uncertain or the felsic rocks directly overlie Mesozoic rocks.

Lithology. The felsic rocks can be divided into two types: massive crystal tuff and thinly laminated flow-layered rocks. The massive tuffs predominate and the flow-layered rocks are only locally important.

The crystal tuff is generally red, brown, or gray with pale red the dominant color. Some of the less consolidated layers, which are particularly abundant in the northwest part of the county, are white to light gray. The massive tuff in places weathers to bouldery slopes, which from a distance closely resemble granitic outcrops. Although most of the tuff is massive, foliation is prominent locally and is shown by elongate pumiceous fragments, obsidian lenses, wispy varicolored patches of groundmass material, and by mineral alignment.

The tuff shows a remarkable similarity throughout the county. Typically it consists of 25 to 30 percent of crystals in a groundmass that is partly glassy, partly crystallized, and in which shard structure is conspicuous. The crystals are generally angular broken fragments, but in part euhedral crystals; they are dominantly oligoclase, quartz, and sanidine with lesser amounts of biotite and hornblende. Foreign fragments are uncommon and rarely larger than 1 inch in largest dimension. Two samples of typical crystal tuff from near Basalt and from Cedar Mountain were analyzed (table 5, nos. 5 and 6); they are closely similar, but the Cedar Mountain specimen is somewhat more felsic. Both are near the boundary between rhyolite and quartz latite in the classification of Rittmann (1952).

Several features of the crystal tuff indicate it is probably welded tuff (ignimbrite). Specific diagnostic features include its large areal extent combined with its massive and locally foliated character and obvious pyroclastic origin. Microscopic features similar to other welded tuff occurrences include biotite flakes bent adjacent to crystal fragments, and shards compressed between adjacent crystal fragments, but with little or no alignment where fragments are absent.

The rhyolitic flow rocks are commonly light shades of gray having well developed thinly laminated flow layering. These rocks locally weather into slabby sheets that split parallel to the flow layers. The flow rocks are characteristically dense with only scattered phenocrysts, commonly feldspar, set in a groundmass of small feldspar crystals and glass. In some of the rocks small flecks of biotite and hornblende are found. The analyzed specimen (table 5, no. 7) from a small body north of La Panta is a more felsic rhyolite than the analyzed crystal tuffs.

The indices of refraction of fused glass beads from selected felsic rocks are shown in the upper row of figure 12. Estimates of the silica content of the rocks made from these indices indicate that the rhyolitic flow rocks are in general higher in silica than the welded tuff specimens; this is in agreement with the chemical analyses. Some of the glass beads from welded tuff specimens, however, have indices of refraction as low or nearly as low as those of the chemically analyzed rhyolitic flow rock, which suggests that the range in silica content in the welded tuffs may be greater than is indicated by the two chemical analyses.

Post-Esmeralda intermediate volcanic rocks

Intermediate volcanic rocks, ranging in composition from rhyodacite to andesite and probably basalt, are abundant and widespread in the county. The maximum thickness of the unit is unknown, but in the Gabbs Valley Range it may exceed 1,000 feet. These rocks rest unconformably on the post-Esmeralda felsic volcanic rocks.

Lithology. The intermediate volcanic rocks are composed of several different rock types, but all are characterized by the presence of phenocrysts of hornblende, augite, or plagioclase, and by the absence of megascopic quartz. Most of the rocks are various shades of gray, but locally dark red rocks are abundant. Volcanic breccia and agglomerate are prominent in this unit and at least locally are more abundant than flow rocks.

These rocks typically have a fine-grained pilotaxitic or hyalopilitic groundmass (in which the glass is crystallized) inset with phenocrysts of plagioclase (oligoclase to labradorite), hornblende

(some is lamprobolite), or augite, and less commonly biotite, hypersthene, or olivine. Most of the rocks examined in thin section would be classified as andesite or basalt without confirmatory chemical data. In many of the rocks the hornblende phenocrysts have been partially or completely resorbed and the phenocrysts are now chiefly ghostlike aggregates of magnetite and hematite. In contrast the augite is fresh in the same rocks. Biotite is outlined in part by a reaction rim of augite and magnetite.

Although thin-section study indicates that this unit is composed chiefly of andesite and basalt, chemical data suggest that the unit is in general more felsic. A "typical" andesite that contained phenocrysts of andesine, augite, hypersthene, hornblende, and biotite set in a fine-grained pilotaxitic groundmass was chosen for chemical analysis. Based upon the chemical analysis (table 5, no. 2) this rock is a rhyodacite, if classified after Rittmann (1952), and is intermediate in several constituents between andesite and dacite with more affinities to dacite, if compared with the average chemical composition of igneous rocks published by Nockolds (1954, p. 1007–1032). The other rock analyzed (table 5, no. 4) is a tuff associated with coarse breccia and agglomerate. It is a quartz latite in the Rittmann classification, but the high aluminum and potassium content suggest that secondary clay minerals may have been developed in the ashy groundmass, and that the analysis may not reflect the original unaltered composition.

Further data on the composition of this unit is afforded by index of refraction studies of fused glass beads. Powdered samples of several of the most mafic-appearing rocks were fused and the indices of the fused beads are plotted in figure 12. The indices show a considerable range, but half of the specimens are more felsic than the rock that was analyzed chemically. The most mafic rocks have silica percentages in the range of basalt. However, it should be remembered that the samples represented on figure 12 are the most mafic-appearing rocks of the unit. In summary, it seems likely that the intermediate group of rocks are mostly dacite and rhyodacite, with some rocks as felsic as quartz latite, others as mafic as andesite, and a minor amount in the basalt range.

Tertiary and Quaternary Mafic Volcanic Rocks

These rocks, called basalt in the field, crop out over a large area of the southern part of the county and are in part continuous with the large area mapped as basalt by Gilbert (1941, p. 787) to the south and west. Their thickness may approach 1,000 feet in the southwest part of the county. The mafic rocks are in general darker colored than the post-Esmeralda intermediate volcanic rocks. The mafic rocks commonly are little changed from their original form and are present as cap rocks, whereas the intermediate volcanic rocks are considerably more eroded and characterized by rounded topography. This preservation of original form suggests that the mafic rocks are at least in part Pleistocene, although Gilbert (1941, p. 787) considers the extensive area of mafic rocks to the southwest to be lower Pliocene.

Lithology

The mafic rocks are invariably medium dark gray to grayish black on fresh surfaces and are commonly vesicular. The rocks are extremely fine grained with inconspicuous phenocrysts. However, small phenocrysts of ferromagnesian minerals and plagioclase are recognizable in some specimens.

These rocks are characterized by a groundmass of plagioclase laths with admixed dark minerals and inconspicuous olivine, hypersthene, or augite phenocrysts. The plagioclase ranges from calcic andesine to sodic bytownite and the rocks, without chemical data, would be designated andesites or basalts.

Chemical analyses, however, indicate these rocks are not andesites or basalts of a calc-alkaline suite. Specimen 1, table 5, is typical of the abundant mafic rocks of the south part of the county; it contains numerous small olivine phenocrysts set in a pilotaxitic groundmass of plagioclase and augite. This rock differs from basalt, however, in its extremely high potassium content; it is a trachybasalt by the Rittmann classification. The other "basalt" analyzed (table 5, no. 3) is a dense grayish-black, vesicular rock with plagioclase, hypersthene, and augite phenocrysts set in a hyalopilitic groundmass. This rock, also, has a high potassium content, and is a quartz latite by the Rittmann classification, but very close to the latite field. Another analysis of a rock called an olivine basalt, which has two percent K_2O and 50 percent SiO_2, is recorded by Gilbert (1941, p. 792) from the Benton Range about 10 miles southwest of the county; this rock is a trachyandesite by the Rittmann classification. Because these rocks are high in potassium they may belong to a trachybasalt to latite suite, rather than to a basalt to andesite suite.

This potassium-rich suite is probably part of what has been called the latite series in the east central Sierra Nevada by G. H. Curtis, J. H. Halsey, and D. B. Slemmons (data referred to and compiled in Nockolds and Allen, 1954, p. 245–285). These workers recognize the latite suite as distinct from a somewhat older calc-alkaline suite in the same area. Quaternary volcanic rocks in the Steamboat Springs, Nevada area near Reno are also high in potassium (D. E. White, written communication, 1959). The Mineral County and Benton Range mafic volcanic rocks are probably related to the latite series, and the older intermediate and felsic rocks are part of the calc-alkaline series. The indices of refraction of the fused glass beads (fig. 12) indicate that most of the mafic rocks are as low or lower in silica than specimen 1, table 5. The range of indices shown bracketed on figure 12 is about the same as the range in the basaltic rocks in the calc-alkaline suite of the Mammoth embayment about 30 miles southwest of the county line (on the basis of work by C. D. Rinehart and the writer). The chemical difference between the calc-alkaline and latite series is not discernible from the bead indices of these mafic rocks of the Mammoth embayment and Mineral County areas.

Quaternary Rocks

The Quaternary rocks consist of a variety of alluvial and lacustrine deposits which, with the exception of the playa deposits, are not differentiated on the geologic map (pl. 2). In the earlier mapping, Ferguson, Muller, and Cathcart (1953, 1954) distinguished a unit of older gravels that are out of topographic accord with the present basin levels. These gravels, which are present in all the ranges, are most abundant at elevations of 5,000 to 6,500 feet and are considered indicative of earlier stages in the development of the ranges.

The younger alluvial deposits consist chiefly of various kinds of basin fill débris from the ranges. Near the range fronts fanglomerate is abundant and the low point of most basins is marked by playa deposits (pl. 2). Two of the playas, Rhodes Salt Marsh and Teels Marsh, contain abundant saline material, whereas the other playas are surfaced dominantly by clay. Locally (particularly east of Huntoon Valley and Teels Marsh) wind-blown sand deposits are present.

Lacustrine deposits, which show that Pleistocene Lake Lahontan extended as far south as Walker Lake, are abundantly exposed in the vicinity of Weber Reservoir. At least 200 feet of strata are exposed in a section consisting of two clay and marl units separated by a sand and gravel layer. These sediments reflect the two major high levels of the lake that are separated by a time of low water (Russell, 1885, p. 138–143). Remnants of the high shorelines of the lake are locally well preserved and are clearly visible on aerial photographs of the area. Beach deposits and shorelines around the isolated basins of Garfield Flat, Teels

Marsh, Soda Springs Valley, and the Rhodes Salt Marsh, which were probably contemporaneous with the last high stage of Lake Lahontan, were also noted by Ferguson, Muller, and Cathcart (1954).

STRUCTURE

REGIONAL SETTING

The alternation of somewhat linear ranges and valleys in Mineral County is typical of the Basin and Range province. The alignment of these features in the county, however, is not typical of most of the province. Throughout most of the Basin and Range province the ranges trend north to northeast, but west of a northwest-trending line (fig. 13), extending northwest from the vicinity of Las Vegas for about 400 miles, the ranges in general trend northwesterly, parallel to the Sierra Nevada, though commonly oriented diversely near the line. The ranges of Mineral County are immediately west of this prominent line of discordance.

The Mineral County ranges show a great diversity of orientation. The Wassuk Range and Cedar Mountain, the largest and smallest ranges in the county, parallel the northwesterly trend of the Sierra Nevada. Between these ranges, the trends are completely anomalous; the most unusual is the S-shaped Gillis-Gabbs Valley-Pilot group. This diversity in orientation suggests that something has disturbed the "army of caterpillars crawling towards Mexico," as Dutton so aptly described the Basin Ranges. The attempt to postulate some important strike slip movement, either along the east front of the Sierra Nevada or, as has previously been suggested, along the line of topographic discordance (Locke, Billingsley, and Mayo, 1940, p. 523), is not, however, in accord with the regional geology. A 4-mile strike slip movement has been postulated in Soda Springs Valley by Ferguson and Muller (1949, p. 29), and strike slip movement has been reported both from faults developed during the Cedar Mountain earthquake of 1932 (Gianella and Callaghan, 1934), and from faults developed during the Owens Valley earthquake of 1872 (Hobbs, 1910, p. 379). The strike continuance of Paleozoic rocks from the Sierra Nevada into the ranges to the east, precludes major lateral movement along the east front of the Sierra Nevada, and the presence of correlative Mesozoic rocks on opposite sides of the line of topographic discordance also limits Mesozoic and later movement across this zone. The possibility remains, though, that the zone of discordance and diversely oriented ranges may mark some fundamental structural break,

probably in the basement rocks, which is reflected in the shape and orientation of the ranges. For discussion and references to this feature the reader is referred to Callaghan in Gianella and Callaghan (1934, p. 18–20).

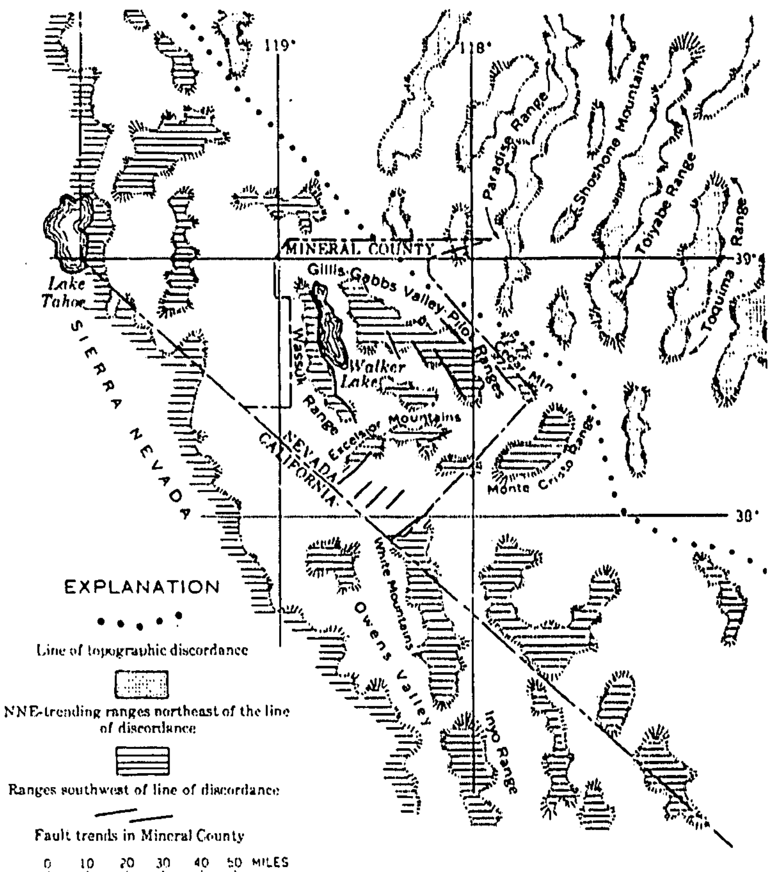


FIGURE 13. Relation of range trends in Mineral County to those in the surrounding parts of the Great Basin, fault trends in the county, and the line of topographic discordance.

STRUCTURAL HISTORY

Summaries of the diastrophic events in Mineral County are found in Ferguson and Muller's report on the structural geology of the Hawthorne and Tonopah quadrangles (1949, p. 7–14) and in the reports on the Coaldale and Mina quadrangles by Ferguson, Muller, and Cathcart (1953, 1954). The following material is essentially abstracted from those reports.

Marsh, Soda Springs Valley, and the Rhodes Salt Marsh, which were probably contemporaneous with the last high stage of Lake Lahontan, were also noted by Ferguson, Muller, and Cathcart (1954).

STRUCTURE

REGIONAL SETTING

The alternation of somewhat linear ranges and valleys in Mineral County is typical of the Basin and Range province. The alignment of these features in the county, however, is not typical of most of the province. Throughout most of the Basin and Range province the ranges trend north to northeast, but west of a northwest-trending line (fig. 13), extending northwest from the vicinity of Las Vegas for about 400 miles, the ranges in general trend northwesterly, parallel to the Sierra Nevada, though commonly oriented diversely near the line. The ranges of Mineral County are immediately west of this prominent line of discordance.

The Mineral County ranges show a great diversity of orientation. The Wassuk Range and Cedar Mountain, the largest and smallest ranges in the county, parallel the northwesterly trend of the Sierra Nevada. Between these ranges, the trends are completely anomalous; the most unusual is the S-shaped Gillis-Gabbs Valley-Pilot group. This diversity in orientation suggests that something has disturbed the "army of caterpillars crawling towards Mexico," as Dutton so aptly described the Basin Ranges. The attempt to postulate some important strike slip movement, either along the east front of the Sierra Nevada or, as has previously been suggested, along the line of topographic discordance (Locke, Billingsley, and Mayo, 1940, p. 523), is not, however, in accord with the regional geology. A 4-mile strike slip movement has been postulated in Soda Springs Valley by Ferguson and Muller (1949, p. 29), and strike slip movement has been reported both from faults developed during the Cedar Mountain earthquake of 1932 (Gianella and Callaghan, 1934), and from faults developed during the Owens Valley earthquake of 1872 (Hobbs, 1910, p. 379). The strike continuance of Paleozoic rocks from the Sierra Nevada into the ranges to the east, precludes major lateral movement along the east front of the Sierra Nevada, and the presence of correlative Mesozoic rocks on opposite sides of the line of topographic discordance also limits Mesozoic and later movement across this zone. The possibility remains, though, that the zone of discordance and diversely oriented ranges may mark some fundamental structural break,

probably in the basement rocks, which is reflected in the shape and orientation of the ranges. For discussion and references to this feature the reader is referred to Callaghan in Gianella and Callaghan (1934, p. 18–20).

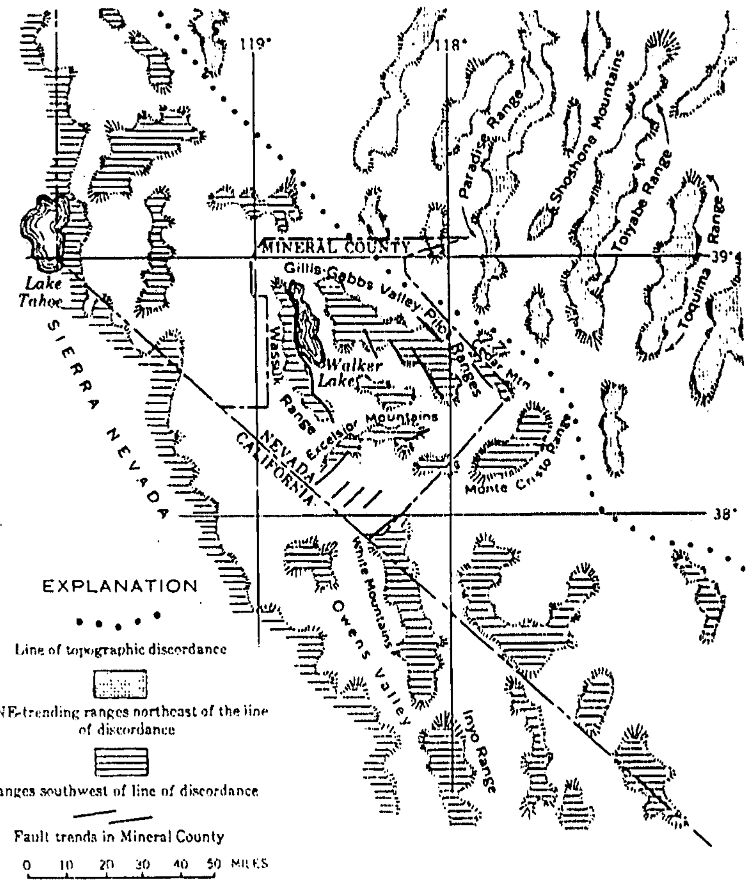


FIGURE 13. Relation of range trends in Mineral County to those in the surrounding parts of the Great Basin, fault trends in the county, and the line of topographic discordance.

STRUCTURAL HISTORY

Summaries of the diastrophic events in Mineral County are found in Ferguson and Muller's report on the structural geology of the Hawthorne and Tonopah quadrangles (1949, p. 7–14) and in the reports on the Coaldale and Mina quadrangles by Ferguson, Muller, and Cathcart (1953, 1954). The following material is essentially abstracted from those reports.

The major period of diastrophism began in the Early Jurassic when intense folding and thrusting deformed the rocks of the Luning embayment area. The Luning embayment is a term applied by Ferguson and Muller (1949, p. 8) to the area in which the conformable sequence of Luning, Gabbs, and Sunrise rocks were deposited. The embayment is believed to represent a local easterly bay along the margin of a broad seaway whose eastern shoreline trended approximately north. Prior to the Jurassic orogeny, there were at least two periods of folding; one prior to the deposition of the Permian rocks, and another later than the Excelsior formation of the Pilot Mountains and the Garfield Hills. The pre-Permian folding was intense as shown by the sharply folded Ordovician rocks overlain in marked angular discordance by Permian clastic rocks in the southern part of the county. In this same area uplift and erosion, which were accompanied by little folding, followed the Permian deposition, but preceded the Lower Triassic Candelaria formation.

A marked angular unconformity separates the Excelsior formation from the overlying Luning formation. If the Excelsior is entirely Middle Triassic this folding occurred between the Middle and Late Triassic. If, however, the Excelsior in the south and east part of the county is Permian, this folding may reflect the same disturbance that uplifted the rocks in the southern part of the county prior to the deposition of the Candelaria formation.

The Jurassic orogeny followed the deposition of about 10,000 feet of conformable strata within the Luning embayment and began with a downwarping that resulted in the deposition of the lower clastic part of the Lower Jurassic Dunlap formation. Folding and thrusting began at the southern margin of the Luning embayment, and from here the disturbance spread northward and was intensified, as shown by the deposition of coarse conglomerates higher in the Dunlap formation. Earlier folds were steepened and overturned, and some earlier thrusts were folded by the later movements. Movement on the thrust sheets was dominantly to the south or southeast. Since the only undisturbed rocks overlying the folded rocks are the sedimentary and volcanic rocks of Miocene and Pliocene age, it is not possible to date precisely the close of the orogeny. The numerous massive, undeformed granitic intrusive rocks which transect folds in the Luning embayment and, in part, intrude along Mesozoic thrust faults, may mark a final phase of the orogeny, or they may postdate the orogeny. These intrusive rocks are probably satellitic to, and may be the same age as the Sierra Nevada composite batholith, which has been dated by radiometric methods as Cretaceous. Some masses, particularly in the eastern part of the county, could be Eocene in age (see table 4). Therefore the major period of folding and thrusting began with the deposition in the Early Jurassic of the clastic Dunlap formation and probably ended or was closely followed by the granitic intrusions of Cretaceous or possibly Eocene age.

Late Tertiary and Quaternary normal faults have at least in part blocked out the ranges (for example, the east front of the Wassuk Range). Two structural trends seem to predominate (pl. 2 and fig. 13), a northwesterly striking set in the eastern part of the county parallel to the zone of topographic discordance, and a northeast striking set in the southern part of the county. The trend of the latter set swings to a northerly alignment south of the county. Normal faulting is still continuing in this area as shown by fault scarps, which have developed as recently as 1954, accompanied by earthquakes in the north part of the county.

STRUCTURE OF THE RANGES

Because the structure of the ranges is generally not similar from one to the next, and also because some ranges have unique features, the structure of each is described separately. A brief statement also is given on the geologic setting of each range, to outline its morphology and types of rocks that are exposed.

The following material is abstracted mostly from Ferguson and Muller (1949), and the reader is referred to that report for a more comprehensive account of the structure of the ranges.

Wassuk Range

The Wassuk Range is the most impressive range in the county. It extends for more than 50 miles in about a N. 20° W. direction and rises more than 7,000 feet from its east base at the shoreline of Walker Lake to the highest peak, Mount Grant, 11,239 feet. The range is markedly asymmetrical with a steep east slope incised by many narrow canyons, and a much less severe western slope; the east slope has grades locally of more than 1,500 feet per mile.

Most of the range is underlain by a composite batholith that contains irregular shaped roof pendants, mostly composed of metavolcanic rocks of the Excelsior formation. Post-Esmeralda Tertiary volcanic rocks are abundant at the north and south ends of the range and locally on the west flank.

Little is known of the detailed geology of the range. However, it is relatively certain that several different granitic intrusives are present and the metavolcanic rocks that make up the roof pendants are of varied composition and include both flows and tuffs. Metasedimentary rocks including marble and gypsum are also found locally in the pendants.

Knowledge of the structure of the Wassuk Range is restricted mostly to the eastern front. Here some excellent examples of range front faults are to be seen. Prominent lineaments and scarps are found at a number of places, but are best developed south of Hawthorne, where an almost continuous arcuate set of faults outlines the base of the range. Scarps in the alluvial fans near the mouths of canyons indicate that some of the movement has been relatively recent. Along much of the range, a single frontal fault is the only obvious break, but east of Powell Mountain the movement has been distributed along several faults. Here a volcanic flow has been stepped down 3,000 feet from the crest of the range to the valley floor. The faulting is not all simple step-faulting toward the valley, however, as some of the faults in this complex area have their downthrown sides toward the range. The presence of both types of faults may indicate a combination of warping and faulting for this segment of the range front. It is significant that where a datum plane (the volcanic flow) is available it is apparent that the faulting was distributive and not solely along a master fault at the range front; possibly distributive faulting is also important elsewhere along the range front, but no datum is available to make it readily apparent.

Excelsior Mountains

The Excelsior Mountains are not particularly well delimited, as they merge westward into the Anchorite Hills and northward into the Garfield Hills, but the range is rather sharply defined along part of its south and east sides. The range is some 30 miles long, about 5 miles wide, and has an arcuate trend from northeast at its western limit to east at the eastern end. The maximum relief is less than 4,000 feet with the summit at 8,766 feet.

A large granitic mass makes up much of the southwestern part of the range and is intrusive into rocks of the Excelsior and Dunlap formations. The rocks of the central part of the range are chiefly Dunlap; to the east Excelsior rocks are the most abundant. Tertiary intermediate volcanic rocks overlap large parts of the southwestern and eastern parts of the range.

The pre-Tertiary structure of the range has been little studied.

The Dunlap and Excelsior formations were folded before the Tertiary, but Mesozoic faulting has not been recorded. The Dunlap formation is unconformable on the Excelsior, but the amount of discordance is not known. The presence of a talus-like breccia at the base of the Dunlap suggests a certain amount of relief when the Dunlap was deposited, but in the area studied in detail by Ferguson and Muller (1949, pl. 14) the contact of the Dunlap and Excelsior is essentially parallel to the attitude of the rocks in the Excelsior formation. The strong folding with local overturning in both formations presumably occurred during the period of folding and thrusting that accompanied and followed the deposition of the Dunlap formation, but some could be the result of the granitic intrusions.

The only prominent faulting in the range is of Tertiary and Quaternary age, which in general follows the trend of the old folded structures and the trend of the range (pl. 2). Two fault systems in the eastern part of the range are of particular interest because they have served to localize mineralized quartz veins. The north-northwest-trending fault system in the Camp Douglas area contains gold-bearing veins, and to the south, faults of the Silver Dyke system are filled with scheelite-bearing quartz. Both of these groups of faults cut post-Esmeralda volcanic rocks. Other significant faults that in places cut rocks as young as Pleistocene parallel the range front east of Marietta and west of Teels Marsh.

The active nature of this area is indicated by the earthquake of January 30, 1934. A 4,500-foot long scarp was developed at that time with a maximum height of 5 inches. The scarp cuts the Excelsior formation northwest of Marietta and trends N. 65° E. along an old fault that parallels the range trend (Callaghan and Gianella, 1935).

Garfield Hills

The Garfield Hills, about 20 miles long and 10 miles wide, are rather subdued except near the east end, where Garfield Peak forms the summit at 8,031 feet. The total relief is about 2,500 feet from Garfield Flat on the south and 3,500 feet from Soda Spring Valley on the north. The hills have essentially an easterly trend but bend to the southeast at their eastern limit.

All the Mesozoic formations of the county except the Candelaria formation crop out in the Garfield Hills; the Luning formation is the most extensively exposed, particularly in the eastern part of the hills. Several granitic masses of various sizes intrude the Mesozoic formations. Much of the western and southwestern part of the hills is covered by Tertiary and Quaternary mafic volcanic rocks.

The Garfield Hills comprise one of the areas where the structure was studied in detail by Ferguson and Muller (1949, p. 19–25). The Garfield Hills provide an excellent record of the Jurassic orogeny as well as evidence of an earlier, post-Excelsior folding.

The first structural events were the uplift, folding, and erosion of the Excelsior formation before the deposition of the Luning formation, as the Luning overlies the Excelsior with angular unconformity. Further folding and uplift, after the deposition of the Luning formation, is evidenced by the unconformable contact of the Dunlap on the Luning and Excelsior formations. The Jurassic orogeny began with deposition of the basal, coarse, clastic rocks of the Dunlap formation. Increased intensity of uplift is recorded by the coarse conglomerates higher in the Dunlap formation, whose pebbles are largely derived from the upfolded Luning formation. Rapid deposition of the Dunlap in a restricted trough is reflected in the marked lateral changes in lithology and thickness of the dominantly coarse clastic rocks (fig. 7). Thrusting along several planes, dominantly toward the south, began after the earlier folding and was a notable feature of the Jurassic orogeny.

The intrusion of the granitic rocks, probably in the Cretaceous, may be considered one of the later events in the Mesozoic orogeny. These intrusions do not seem to have disturbed notably the already folded and faulted rocks, but judging by their linear outcrops and relation to mapped thrusts, some of the granitic rocks were apparently intruded along thrust planes.

Tertiary and Quaternary faulting was of minor importance in the Garfield Hills. Only along one small segment of the range southwest of Luning is there physiographic evidence of a range front fault. Along the north side of the range the front is irregular and subdued and shows no signs of fault movement.

Candelaria Hills and Miller Mountain

The Candelaria Hills and Miller Mountain form a northeast-trending topographic unit along the southeastern side of the county. Miller Mountain, at the south end, is 8,708 feet high; the Candelaria Hills bound it on the north and slope gently from a summit of slightly over 7,000 feet to valleys at altitudes between 5,000 and 6,000 feet.

This area is underlain by Cambrian, Ordovician, Permian, and Lower Triassic formations, which are largely confined to this part of the county. Intrusive rocks of probable Cretaceous age are uncommon and occur mostly as small dikes. Some bodies of serpentine are exposed south of Candelaria. Tertiary felsic welded tuff and lesser amounts of the Tertiary and Quaternary mafic volcanic rocks cover large parts of the area.

The earliest orogeny in the county is recorded by the angular unconformity that separates the tightly folded Ordovician rocks from the overlying, less steeply dipping Permian Diablo formation. Following the deposition of the Diablo, much of that formation was removed by erosion before the deposition of the Lower Triassic Candelaria formation. This period of uplift and erosion apparently involved little folding as the Diablo and Candelaria are nearly parallel in attitude. The rocks of the Candelaria area have not been involved noticeably in the later Mesozoic orogeny. East of the county line, however, the Diablo formation is thrust over the Ordovician rocks, and the Ordovician rocks are in turn thrust over the Excelsior formation.

West of Candelaria the Candelaria Hills form a horst block between two east-northeast-trending fault valleys. Other faults in the area also generally trend northeast to east. Rocks as young as the mafic volcanic rocks of Quaternary age are involved in this faulting.

Gillis Range

The Gillis Range is delimited from the Gabbs Valley Range by low passes to the east of the main Gillis Range crest line. It is about 30 miles long, about 6 miles wide, and is arcuate in shape, changing from a westerly trend at the southern end to almost due north at the northern end. The summit of the range is just under 8,000 feet, and the total relief is almost 4,000 feet to the west base of the range near the shore of Walker Lake.

All of the Mesozoic formations except the Candelaria are exposed in the Gillis Range. The Excelsior formation is the most extensive and underlies large areas along the west flank and the crest of the range. The Luning formation is extensively exposed on the east flank of the range. Granitic rocks of probable Cretaceous age underlie large areas of the range, especially in the east-trending part of the range. The northern part of the range is mostly covered by post-Esmeralda felsic volcanic rocks of Tertiary age.

Except for small areas on the east flank of the range where the Gillis thrust was studied, the structure of the Gillis Range is known only from reconnaissance surveys. The Gillis thrust is exposed at several places along the east front of the range.

Movement along this thrust has brought the Excelsior formation over the younger Luning formation. A continuation of this thrust is postulated by Ferguson and Muller (1949, p. 17, 24) in the structurally complex area in the northwest part of the Garfield Hills. The possible significance of this thrust is more fully discussed in connection with the Excelsior formation (see p. 20).

A prominent fault scarp bounds a protruding segment of the range northeast of Kincaid and extends northwest through the range. Conspicuous range-front faulting is not apparent elsewhere along the range front.

Gabbs Valley Range

The Gabbs Valley Range is the central part of the S-shaped mountain block that includes the Gillis Range and the Pilot Mountains. The range is about 35 miles long, extending north from the low pass that marks the boundary with the Pilot Mountains to the vicinity of Nugent Wash. North of the wash, the range merges to the west with the north end of the Gillis Range, and an eastern spur of low hills connects with Pilot Cone and the hills around Rawhide. The summit of the range is at 8,360 feet, and the maximum relief is somewhat more than 3,000 feet.

The southern part of the range is underlain chiefly by the Luning formation, but granitic stocks underlie large areas and the Gabbs, Sunrise, and Dunlap formations also are present. Most of the range is covered with intermediate and felsic Tertiary volcanic rocks, and north of Sunrise Flat the range is almost completely covered with volcanic rocks.

The southern part of the range is one of the areas studied in considerable detail by Muller and Ferguson. In general the rocks are less intensely folded here than in the Garfield Hills to the west and in the Pilot Mountains to the south, but the same structural relations are found. The coarsely fragmental Dunlap rocks signify the beginning of the Jurassic orogeny after a period of continuous deposition through the Late Triassic and earliest Jurassic. Thrusting, predominantly to the south, reflects a later phase of the Jurassic orogeny; it is common east of Sunrise Flat. In this area, "thrust conglomerate" lenses along some of the thrusts are of particular interest. Ferguson and Muller (1949, p. 27–28) interpret these lenses as erosional debris from the front of an advancing surface thrust sheet. Alternate periods of thrusting and quiescence resulted in the thrust overriding material eroded from the scarp during stable intervals.

Cenozoic faulting is prominent in this range, and faults that trend mostly northwest have been mapped along both flanks and within the range. Some tilting has accompanied this faulting in the Sunrise Flat area. The front of the range that bounds Soda Spring Valley is probably faulted along its entire length, but only the more obvious faults are shown on the map. These faults trend northwest, even along the segment of the range that trends nearly east parallel to the Garfield Hills.

The northern segment of this frontal fault system, which separates granitic rock from rhyolite tuff, presents a problem in interpretation. The rhyolite tuff, although much younger and less resistant to erosion than the granitic rock, is locally topographically higher. This anomalous position of the rhyolite was used by Ferguson and Muller (1949, p. 29) as supporting evidence for the possibility of right lateral strike-slip movement on the fault along the east side of Soda Spring Valley. Further examination of this area in 1956 by the writer, with the aid of air photos, confirms a fault contact and additional parallel faults in the rhyolite near the contact, but the faults could only be traced part way through the range. In the softer rhyolite the fault may be obscured, but it is surprising that no strong linear element is visible on the air photos, as is evident in connection with many of the other Cenozoic faults of the county. Reversal of the 4-mile movement postulated by Ferguson and Muller (1949), however, would bring the granitic rocks north of Volcano Peak adjacent to the large stock west of the fault, and would also bring the topographically higher rhyolite west of the fault in the crestal area of the range. Further evidence of the possibility of strike-slip movement along this fault will be discussed in connection with the Pilot Mountains and Cedar Mountain.

Pilot Mountains

The Pilot Mountains are a southward continuation of the Gabbs Valley Range. The shape of this part of the mountain block is almost that of a square 10 miles on a side with northerly trending crest lines. The west slope rises steeply and abruptly more than 3,000 feet from the edge of the valley at about 4,800 feet; it is incised by rugged canyons and presents a very formidable appearance. The highest peak is Pilot Peak, which at 9,207 feet is the highest point in the county east of the Wassuk Range.

Mesozoic formations underlie practically the entire range. The south half is underlain almost exclusively by the Excelsior formation into which several small stocks of granitic rock have been intruded. North of the area underlain by Excelsior rocks, the

Dunlap formation is exposed in an irregular band and the northern part of the range is underlain chiefly by the Luning formation.

The Pilot Mountains, because of the large area of well exposed Mesozoic rocks, are an excellent place to study the complex Mesozoic structure. Ferguson and Muller have described this area in detail and the following excerpt from their report (1949, p. 29–38) summarizes the Mesozoic structural history:

"The Excelsior formation . . . was strongly folded and overturned to the north prior to the warping and sinking that permitted the deposition of the Luning, Gabbs, and Sunrise formations. The lower part of the Dunlap formation was deposited in a basin, which overlapped the contact of Luning and Excelsior. The beginning of the Jurassic folding was marked by the formation of a local trough within this basin. This trough received the conglomerate and fanglomerate from the rising folds and incipient thrusts to the north. Apparently local deepening of this trough accompanied the early folding and thrusting in the area now included in the northwestern part of the range. The earlier folds and thrusts * * * were themselves strongly folded by pressure from the north that developed a large recumbent fold and additional thrusts. This folding and thrusting appears to have been local and determined by the position of the trough that received the detritus from the Luning formation on the north while the early folding and thrusting were in progress. The deformation may have been complicated by irregularities in the original surface of deposition . . .

"It is believed that the northwestern part of the range, compacted by early close folding, was uplifted and acted as a partial obstruction to later more widespread folds."

Cenozoic faults are conspicuous along the west and north flanks of the range, but less obvious on the east side. The west slope of the range is one of the best examples of a fault scarp in the county (fig. 14). The front is linear, there is an abrupt change in slope from valley to range, structural trends and attitudes of beds within the range are oblique to the front, and in addition the trace of the fault has been mapped through small bedrock spurs that extend beyond the front. This scarp appears to end abruptly at Mac Canyon (fig. 14). However, its northward extension may be along the fault that trends northeastward from Mac Canyon. This fault has a scarp, downthrown to the west, that is essentially continuous with the frontal fault. If this interpretation is correct, there probably has been no significant strike slip movement along the west front of the Pilot Mountains, as the Luning formation is not appreciably offset along the fault in Mac Canyon. Ferguson and Muller had previously suggested

(1949, p. 14) a strike slip fault in Soda Spring Valley to explain the offset position of the contacts and thrusts from the Pilot Mountains to the Garfield Hills, as well as the anomalous position of the granitic and rhyolitic rocks north of Luning in the Gabbs Valley Range (see p. 66). They postulate a right lateral movement of about 4 miles, which if reversed to a hypothetical

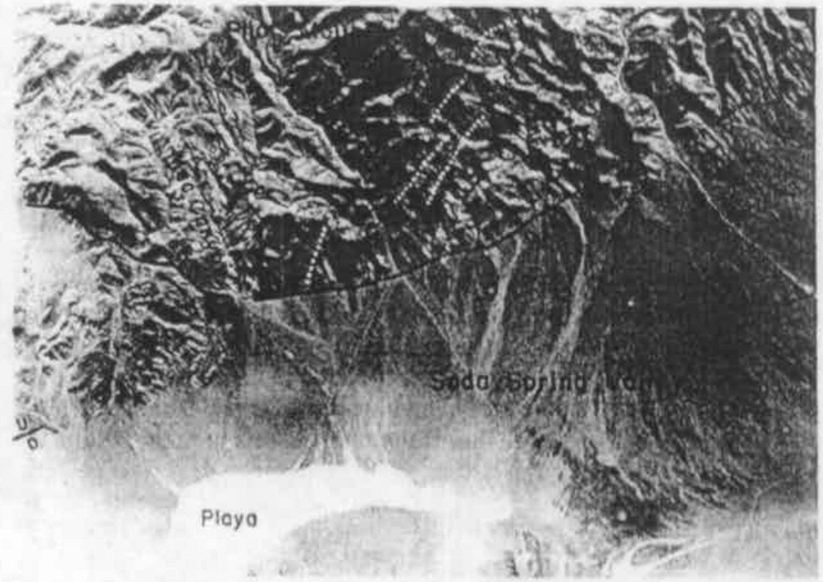


FIGURE 14. Aerial photo of faulted west front of the Pilot Mountains. Scale approximately 1 inch = 1 mile. Solid and dashed lines along front of range are faults; dotted lines in range show trends of bedding.

original position brings several of the thrusts and contacts in close alignment. This fault could possibly be present to the south, but if so, it must lie in Soda Spring Valley west of the frontal fault along the Pilot Mountains.

Cedar Mountain

Cedar Mountain is a relatively narrow ridge extending in a northwesterly direction for about 25 miles, but only about the northern two-thirds of the range is within Mineral County. The highest point is about 8,100 feet, and the maximum relief is about 1,500 feet. The slopes are gentle and as a consequence the rocks are commonly poorly exposed. Cedar Mountain and the low range of hills immediately east in Nye County mark the eastern limit of the northwest and westerly trending ranges of Nevada. All the ranges to the east trend north to northeast (fig. 13).

The Luning formation underlies a large part of the northern part of the range, and is intruded by stocks of granitic rock. The Dunlap formation crops out in a narrow syncline near the southeast county boundary. Farther south is a small outcrop of Excelsior. Tertiary volcanic rocks are common both north and south of the main blocks of Mesozoic rocks, and the most extensive exposures of pre-Esmeralda volcanic rocks in the county are in this range.

Cedar Mountain has been studied only briefly, but scattered observations in the northern part of the range suggest the Luning formation is gently folded and generally trends northwest. To the south the folds are steeper, but thrusting is minor in the range. The folds of Cedar Mountain are in general aligned with the folds in the Pilot Mountains.

Cenozoic faults have been mapped at several places along the west front of the range, as well as in the interior of the range in the Tertiary volcanic rocks. Knopf (1921, p. 370) noted that both at the Olympic mine and west of the Simon mine the Esmeralda formation is faulted against the older rocks. The west front of the range is probably entirely fault bounded, but the combination of soft rocks and gentle slopes tends to conceal the faulting, except where it has been recently active.

Evidence that this area is still tectonically active came during the earthquake of December 20, 1932 when a number of small faults formed in the valley between Cedar Mountain and the Pilot Mountains (Gianella and Callaghan, 1934). Horizontal movement on some of the faults and arrangement of the faults in an echelon pattern suggests the major movement may have been horizontal with the east side (Cedar Mountain) moving south in reference to the west side (Pilot Mountains and Gabbs Valley Range). Callaghan (Gianella and Callaghan, 1934, p. 18–22) suggests that this recent faulting may reflect the kind of movement that is characteristic of the zone of topographic discordance between the dominantly northwest-trending ranges and the dominantly north- to northeast-trending ranges. Ferguson and Muller (1949, p. 14, 39) point out, however, that the valley between the Pilot Mountains and Cedar Mountain can hardly be a zone of major strike slip movement because of the seeming continuity of structures and rock distribution between the two ranges. They further suggest that a zone of movement may be along the east side of Soda Spring Valley and that the earthquake faults reflect a subsidiary fault zone of no great movement.

It seems more probable, however, that whatever the major controlling structure is, it is reflected by the zone of topographic discordance east of Cedar Mountain, and that both of the features to the west are subsidiary to some as yet unexplained feature.

Other Areas

Included here are the predominantly volcanic hills and the small segment of the White Mountains (in the south part of the county), the predominantly volcanic terrane around Aurora (along the southwest edge of the county), and the hills underlain by Tertiary volcanic rocks, the Excelsior formation, and small granitic masses in the Rawhide-Eagleville area (in the north part of the county).

In the southern part of the county the extreme northern tip of the White Mountains extends into the county and the rocks exposed consist of Cretaceous(?) granitic rocks that intrude schists of uncertain age. Tertiary felsic volcanic rocks overlie these to the north. A series of echelon frontal faults bound the west flank of the range at the north end; each parallels the front for short distances before extending into the range. Faults are locally abundant in the Tertiary rocks in the area northwest of the White Mountains to Aurora Valley. Almost invariably they strike northeast, suggesting that possibly the structural grain in this part of the county is northeast parallel to the western end of the Excelsior Mountains.

Tertiary volcanic rocks cover most of the Aurora area; exceptions are small windows in which the Excelsior formation and Cretaceous(?) granitic rocks are exposed. Little is known of structure of the area. In his reconnaissance of the Aurora district, Hill (1915) found that many of the mineralized veins that cut the pre-Esmeralda volcanic rocks strike northeast and dip steeply. A mineralized vein with a steep dip and a northeast trend cuts rock of the Excelsior formation in the small window about 8 miles northwest of Aurora. These isolated examples also suggest the prevalence of a northeast structural trend in the southwest part of the county.

Only a small amount of detailed geologic work has been done in the Rawhide-Eagleville area. In an investigation of the Nevada Scheelite mine, K. B. Krauskopf and R. F. Stopper (written communication, 1946) found three sets of steeply dipping faults cutting Excelsior rocks, but apparently not the granitic intrusives. The sets trending northeasterly and northwesterly are the most numerous; those trending easterly are less abundant. Faults that cut the granitic rocks and most commonly trend northeast also are well exposed in the mine workings, although not easily recognizable on the surface.

About 6 miles east of Eagleville a north-trending ridge is bounded on the west by a fault that was reactivated during the Fairview Peak-Dixie Valley earthquake of December 16, 1954. A west-facing scarp with a maximum height of 18 inches was developed at that time. This earthquake also resulted in scarps on the other faults shown on plate 2 in this area and a few miles north of the county produced scarps as high as 12 feet (Slemmons, 1957). These faults are all associated with the north- to northeast-trending ranges east of the line of topographic discordance, in contrast to the Cedar Mountain fault scarps developed during the earthquake of 1932 that are west of the line; the faults of both areas have a similar trend, however.

MINERAL DEPOSITS

Mineral County has been appropriately named because of its great variety of mineral deposits. Silver, gold, tungsten, copper, lead, zinc, iron, manganese, and mercury are the metals, and fluorspar, borax, sodium chloride, sodium carbonate, sodium sulfate, gypsum, clay, diatomaceous earth, barite, turquoise, marble, serpentine, and aluminous minerals (chiefly andalusite) are the nonmetals that have been produced.

Several types of mineral deposits are found. In the metallic group, fissure vein deposits are the most common and in the past were the most important, as they accounted for almost all the precious metal production. Contact metamorphic deposits were the most productive in the mid-1950's, particularly the scheelite-bearing tactite deposits, which are the major source of tungsten in the county. Much of the copper also came from contact metamorphic deposits. Replacement of limestone by sulfides was locally a source of silver-lead-zinc ore. In addition placer deposits have accounted for a small part of the gold production. The nonmetallic deposits include fissure veins of fluorspar and barite, and replacement deposits of aluminous minerals in volcanic rocks. Various salts, clay, and diatomaceous earth have been extracted from selected layers in the Tertiary lake deposits and the playas.

About 20 mining districts have been established in Mineral County. The inset on plate 1 shows the location of the districts, but as some have had several names and contiguous districts overlap, some of the designations of boundaries and names may differ from local usage. In this report, data on about 200 properties

of these districts are listed in table 6 and most of these properties are located on plate 1. These tabulations do not represent a complete list of the properties in Mineral County. Omissions were inevitable, particularly of some of the older mines, and for some of the districts dozens of mines had to be grouped together because of lack of data on individual properties. Descriptions are in general more complete for the recently active properties, chiefly because they are accessible and data are available as a result of investigations by the U. S. Geological Survey during and after World War II. Sources of data on table 6 are noted in the column marked "References." Information on properties for which there is no reference was gained mainly by visits of the author.

HISTORY

Mining activity in Mineral County began with the discovery of the Aurora gold deposits in 1860. The exploitation of these rich deposits was followed by the location of the silver veins of Candelaria by a Spanish party in 1863. Together these two districts in the period 1861–1891 accounted for more than half of the total mineral production of the county to 1956. In addition these two districts furnished a mining population to the county and served as a great impetus to prospecting.

Most of the other districts of the county were discovered during the interval of peak production at Aurora and Candelaria. Marietta was first in the 1860's, followed by the Indian Queen mine in the Buena Vista district in 1870, and several areas in the Hawthorne district later in the 1870's. In 1879 the Santa Fe district was located and the original discoveries at Cedar Mountain were made. Early in the 1880's the Garfield district was established.

Paralleling the development of the metallic deposits, the saline playa deposits of Rhodes Salt Marsh and Teels Marsh were exploited in the 1860's and 1870's for salt to aid in the extraction of the ores of the Comstock,[7] Aurora, and Candelaria districts. An interesting sidelight of this period was the use of camels to transport the salt from Rhodes Salt Marsh to the Comstock district near Virginia City. This was one of the few commercial uses of camels in this country. In 1872 the first discovery of borax in Nevada was made at Teels Marsh and shortly thereafter borax was also found at Rhodes Salt Marsh. Both playas were borax producers until the discovery of the Death Valley

[7]About 110 miles northwest of the marshes.

deposits in 1892. The playas have also had minor production of other salts.

Adverse economic conditions in the early 1890's marked the beginning of an extremely lean period in mining in Mineral County. During this depression period, the gold veins of the Camp Douglas area of the Silver Star district provided practically the only production for the county. Then with the discovery of Tonopah in 1900, most miners who were left in the county moved to Tonopah, and it was not until the Rawhide discovery in 1906 that mining activity began to increase again in the county.

Shortly before World War I, cinnabar was discovered in the Pilot Mountains, and this district became an intermittent producer of quicksilver from 1915 to the late 1940's. The demand for metals that accompanied World War I was reflected in Mineral County chiefly by copper production from the Santa Fe district, and tungsten production from the Silver Dyke mine, discovered in 1916. Shortly after World War I, mining activity shifted to Cedar Mountain. Here, the Simon mine became a moderate silver-lead-zinc producer during the early 1920's upon the discovery of a rich sulfide zone beneath a gossan that had first been located in 1879. Also during the 1920's the Olympic mine in the same area produced a moderate amount of gold.

The general economic collapse at the end of the 1920's was reflected in low mineral production throughout the early 1930's. A small resurgence in production was noted from several of the districts in the late 1930's, and in the 1950's tungsten production in particular was stimulated by a government purchasing and stockpiling program. The Nevada Scheelite mine, discovered in 1930, began producing in 1937 and was the outstanding producer in the county throughout the first half of the 1950's. In 1951 the price of tungsten was raised and fixed by government order, and the mine's tungsten production increased rapidly. By 1955 the annual production was approaching values equal to that of Aurora in the 1860's.

In the summer of 1956 only two properties were making significant production; Nevada Scheelite, and the Kaiser (Baxter) mine, which has been producing fluorspar almost continuously since its discovery in 1928. Both of these properties ceased operation early in 1957 because of the termination of the government stockpiling and price support program. There was limited silver-lead production from the Candelaria district in 1956, and several small tungsten mines in the county had been intermittently active in the first half of the 1950's. Prospecting activity in 1956 was concentrated on tungsten, mercury, and uranium, with less emphasis on silver-lead, gold, iron, and copper properties.

PRODUCTION

Figure 15 shows the annual county production from 1861 to 1957 and graphically illustrates the peaks of production, which generally reflect individual district or mine production. Table 7 gives the approximate district production totals, chiefly from Couch and Carpenter (1943) and Vanderburg (1937).

The total production of Mineral County from the first mining at Aurora in 1861 to the end of 1956 is estimated at between $74,000,000 and $80,000,000.[8] Production figures to the end of 1940, totaling about $55,400,000, are taken chiefly from the report of Couch and Carpenter (1943), which is based on tax records. These are minimum figures; other sources which list higher productions from some districts, particularly Aurora and Candelaria, would possibly raise this total by $10,000,000.

METALLIC DEPOSITS

In the following summary the geology of major deposits and interesting occurrences of each commodity will be briefly discussed, followed by short statements on each district. For readers who desire information on individual properties, most of which are located on plate 1, table 6 is arranged alphabetically by districts. More information on the mineral deposits is available from some of the papers listed in "References cited" in this report, and in the "Bibliography of Geologic Literature of Nevada" by V. P. Gianella (1945), which is arranged alphabetically by county and district.

Silver

Silver has the highest value of the metals produced in Mineral County and most of it came from Candelaria and Aurora. The impressive production of Candelaria (from $14,000,000 to $20,000,000, depending on the source of data) was dominantly silver with lesser amounts of lead and minor amounts of antimony. The ore was mined from oxidized veins, which generally were 10 to

[8] In figure 15, for the period 1910 to 1934, figures from Vanderburg (1937, p. 10) are used, which are higher than figures from Couch and Carpenter (1943, p. 99) for the same interval. This accounts for a total production of about $80,000,000 (if the fluorspar production is included), whereas table 7 is based in part on district totals of Couch and Carpenter (1943), and hence totals only about $74,600,000.

20 feet thick and filled with a soft ferruginous and manganiferous material in which sulfides were rarely seen. At depth the unoxidized vein filling was manganiferous ferrodolomite containing pyrite, sphalerite, galena, and jamesonite. The sulfide ore

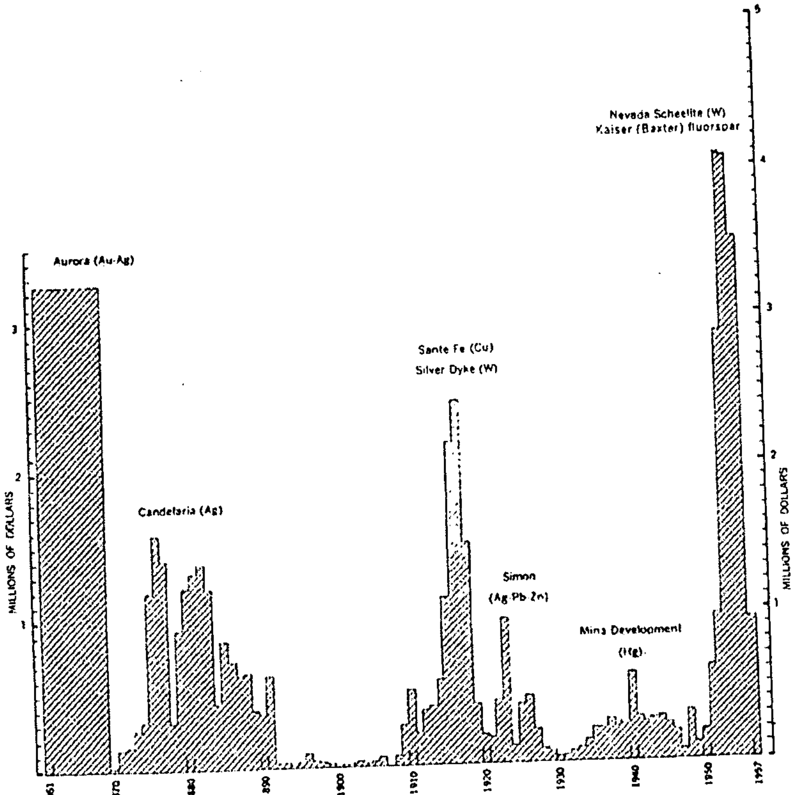


FIGURE 15. Value of mineral production of Mineral County, Nevada, from 1861 to 1957, exclusive of production at Kaiser (Baxter) mine from 1941 to 1952. Districts, mines, and commodities shown accounted for major output during indicated periods of peak production. Data for the periods 1861 to 1909 and 1935 to 1940, mainly from Couch and Carpenter (1943); for the period 1910 to 1934, Vanderburg (1937). Miscellaneous data for the period 1941 to 1952, published with permission of the Nevada Scheelite Corp.; from Bailey and Phoenix (1944); and from Phoenix and Cathcart (1952). Data for the years 1953 to 1957 from Minerals Yearbooks of the U. S. Bureau of Mines.

could not be handled in the 1800's but some of the production in the 1950's was from sulfide ore. In the early days of the district the ore averaged 60 ounces of silver per ton, but by the

TABLE 7. Mineral production of major districts, Mineral County, Nevada*

District	Years	Commodity	Value	References
Aurora	1859–1940	Gold, silver.	$31,409,000	Couch and Carpenter (p. 100).
Bell	1917–1939	Silver, lead, zinc, gold.	1,012,000	Couch and Carpenter (p. 104).
Bovard	1910–1935	Copper, gold, silver, lead.	363,000	Vanderburg (p. 56).
Broken Hills	1935–1940	Lead, silver, zinc, gold.	180,000	Couch and Carpenter (p. 101).
	1935–1940	Fluorspar.	190,000	Couch and Carpenter (p. 104).
	1941–1957	Fluorspar.	5,700,000	Company data, published with permission.
Candelaria	1870–1954	Silver, gold, lead, copper.	15,029,000	Page (p. 13).
Fitting	1912	Gold, silver, lead, copper.	2,000	Couch and Carpenter (p. 100).
Garfield	1884–1940	Silver, gold, copper, lead.	1,376,000	Couch and Carpenter (p. 101).
Hawthorne	1874–1939	Silver, gold, lead, copper.	1,086,000	Couch and Carpenter (p. 102).
Mount Grant	1873–1935	Gold, silver.	303,000	Couch and Carpenter (p. 101).
Mountain View	1916–1917	Copper, gold, silver, lead.	29,000	Couch and Carpenter (p. 102).
Pilot Mountains	1912–1943	Mercury, silver, gold, lead.	390,000	
Regent	1908–1940	Silver, gold, lead, copper.	957,000	Couch and Carpenter (p. 102).
	1937–1956	Tungsten.	12,000,000	Company data, published with permission.
Santa Fe	1885–1940	Copper, silver, gold, lead, antimony.	1,196,000	Couch and Carpenter (p. 103).
Silver Star	1872–1940	Tungsten, silver, lead, copper, gold.	1,810,000	
Rhodes Marsh	1884–1934	Borax, salt.	200,000	Couch and Carpenter (p. 102).
Teels Marsh	1874–1893	Borax, salt.	930,000	Couch and Carpenter (p. 103).
			$74,662,000	

*Production figures based on best available records. Inclusion of unrecorded years and smaller districts would increase total production value. Commodities listed in order of importance.

1920's the average had dropped to 10 to 15 ounces of silver per ton (Knopf, 1922, p. 14–15). In the only active underground operation at Candelaria in 1956 (New Potosi mine) the sulfide ore being produced contained as much as 10 ounces of silver, 10 percent of lead, 6 percent of antimony, and half an ounce of gold per ton.

The silver production of Aurora may have been around $10,000,000, but as most figures are for total production, this figure is estimated from the small recorded silver production, and from the approximate silver to gold ratio of the district as recorded by Ferguson (1929).

The following properties account for most of the rest of the silver production; the Simon mine in the Bell district, the Lucky Boy mine in the Hawthorne district, the Mabel and Garfield mines in the Garfield district, and several mines in the Marietta and Fitting districts. The Simon mine, which is described by Knopf (1922, p. 370–375), is a replacement body in limestone. Ore bodies containing principally galena and sphalerite were localized along a fault and an alaskite dike; according to Knopf (1921, p. 370), the ore averaged 5 ounces of silver per ton. Most of the other silver production has come from fissure veins that were filled with quartz and various sulfides, most commonly argentiferous galena.

Some silver has been produced from reworked dump material. During World War I about 125,000 tons of dump material from the Candelaria district were milled by the cyanide process at Belleville. In 1956, the Northern Belle dump, being reworked by the Argentum Mining Co., was reported to average about 6 ounces of silver per ton.[9]

Gold

All of the gold properties in the county were also silver producers, but for those that are more noted for gold, Au is shown first in the list of commodities in table 6. The great bulk of the gold production of Mineral County came from the Aurora district (approximately $21,000,000). Here a series of northeast- to east-striking, anastomosing quartz veins, as much as 80 feet thick, were mined extensively in the 1860's. The veins are in pre-Esmeralda volcanic rocks that are exposed as a window in an area of predominantly barren younger volcanic rocks. Hill (1915, p. 141–150) describes the district and states that the rich ore is marked by irregular wavy streaks of quartz, adularia, argentiferous tetrahedrite, small amounts of pyrite and chalcopyrite, and a soft bluish-gray mineral supposed to be a combination of gold and possibly silver with selenium. Free gold was found in the richer ore and was particularly abundant in some of the older stopes. In general the Aurora ore was low grade with the average tenor about $6 to $8 per ton although some of the richest shoots ran as high as $1,000 per ton. The gold to silver ratio ranged from 1:5 to 4:2 according to Hill (1915, p. 150), but was recorded as 1:14 by Ferguson (1929); the latter ratio probably represents a better figure for the district.

[9]Both the Argentum Mining Co. and the New Potosi mine were inactive as of publication date (editors).

Other gold producers in the county were the Camp Douglas group in the Silver Star district, the Olympic mine in the Bell district (Cedar Mountain), the La Panta-Pamlico area in the Hawthorne district, the Rawhide area of the Regent district, and the Belleville mine in the Pilot Mountains.

The Camp Douglas veins have clean and sharp contacts with clastic rocks of the Dunlap and Excelsior formations and contain only gold and silver in addition to the quartz filling. Similar veins are found at the Olympic mine, cutting the pre-Esmeralda volcanic rocks, where the gold and silver were present as electrum and were not visible in hand specimens. In several of the districts, post-mineral faulting has developed gouge along the veins and partially crushed the ore. Free gold occurs in a soft gangue of mostly iron oxide in some veins where sulfides were abundant and have been extensively oxidized, as at La Panta. In the Rawhide district, free gold has been mined both from quartz veins and from kaolinized areas in rhyolite. A somewhat similar association to the latter is found in the eastern part of the Camp Douglas area, where free gold is found in crushed and hydrothermally altered andesite. Rawhide was also the site of a minor amount of placer mining, chiefly by dry wash methods. Reworking of dump material has also yielded some gold both at Aurora and at the Belleville mine (in the Pilot Mountains), during and shortly after World War I.

Unfortunately, data on the grade of ore from districts other than Aurora are limited. Most deposits would probably be classed as low-grade, although there were high grade shoots in most districts. In part the high grade shoots were the result of surface enrichment, as at La Panta.

Tungsten

Tungsten production, which in 1956 ranked third in total dollar value, has risen spectacularly in the county since 1950. This is due almost entirely to activity at the Nevada Scheelite mine in the Regent district. This mine, discovered in 1930, had to the end of 1956 produced about 277,000 short ton units of WO_3, which sold for about \$12,000,000.[10] The deposit is in a contact metamorphic mass of scheelite-bearing tactite that has developed from limestone along a contact with a granitic stock. Much of the tactite in the upper levels of the mine has been oxidized to a soft, limonitic material in which several percent of WO_3 is found locally in the form of ferrotungstite. The average grade of ore treated has been about 1 percent of WO_3. Several smaller mines near the Nevada Scheelite mine have produced small tonnages, particularly in the early 1950's.

The second most important source of tungsten in the county is the Silver Dyke vein system in the Silver Star district (Kerr, 1936). Several mines along this vein system have produced ore having a total value of more than \$1,200,000 during and in part after World War I. The Silver Dyke is a steeply dipping discontinuous quartz vein system that is locally several hundred feet thick and extends for about 3 miles. The vein system cuts diorite, the Excelsior formation, and Tertiary andesitic volcanic rocks (Kerr, 1936, p. 42), which are presumably of post-Esmeralda age. Scheelite is sporadically disseminated in the quartz and locally is coarse and very high-grade; sufides are not common. The name Silver Dyke is the result of a small silver production from the upper part of the vein, made shortly after the discovery.

Other tungsten properties are found in practically every district in the county, but none have been as productive as the Nevada Scheelite or Silver Dyke mines. The Gunmetal mine near the east base of the Pilot Mountains and some of the mines of the Santa Fe district (T. 8 N., R. 35 E.) have had production, chiefly during and after World War II. These properties are developed in scheelite-bearing tactite bodies which formed from limestone along or near contacts with granitic rock. Most are low-grade deposits, but locally they contain ore that averages 1 percent or more of WO_3. The Pine Crow property in the Black Mountain district has no known production, but is interesting for it is the only occurrence in the county of scheelite and wolframite together in a quartz vein.

Copper

The most significant copper production was made in the Santa Fe district during World War I. From 1916 to 1918 copper valued at over \$1,800,000 was produced from this district (Vanderburg, 1937, p. 69). The largest producers were the Wallstreet and Turk mines with an aggregate production of nearly \$1,000,000 (Couch and Carpenter, 1943, p. 106). These two mines were developed on a veinlike deposit as much as 30 feet thick in which azurite, malachite, chrysocolla, and cuprite are present in fissures in limestone. Most of the other ore produced in the district came from similar types of deposits, but several of the mines were developed in tactite zones along contacts between granitic rocks and limestone. The primary copper mineral in the tactite was probably chalcopyrite, which has been altered chiefly to copper carbonate minerals. Some of the other mines are developed on breccia zones along faults where disseminated primary copper has been oxidized and concentrated. Additional data on the Santa Fe district are available in Hill (1915, p. 157–171) and Clark (1922).

Elsewhere in the county, copper staining is widespread but only a small amount of copper has been produced from scattered localities in several districts, all from secondary copper minerals. Total production outside of the Santa Fe district, however, does not exceed a few hundred thousand dollars.

[10]Production figures published with the permission of the Nevada Scheelite Corporation.

Mercury

Almost all of the mercury production of the county came from the Pilot Mountains during World Wars I and II. This district is thoroughly described by Phoenix and Cathcart (1952, p. 143–171). The total production has been about 5,000 flasks of which about 3,000 flasks have come from the Mina Development Co. mine. The only mercury ore mineral, cinnabar, occurs as massive fracture fillings, as disseminated grains in fault gouge, and as a replacement of various sedimentary rocks, chiefly limestone.

The Wild Rose mine in the White Mountains south of Mount Montgomery, near the Esmeralda County line, is the only property outside of the Pilot Mountains to exceed a 100-flask production. At this property cinnabar is disseminated in opalized rhyolite along a fault zone.

Lead-Zinc

None of the mines of Mineral County except the Simon mine were primarily lead or zinc producers. The total lead production of \$600,000 listed in table 7 may be conservative, as the amount of by-product lead during the productive span of the major silver mines in the 1800's is generally unknown. The only mine that is known to have produced zinc is the Simon mine in the Bell district. Although this mine is chiefly thought of as a silver mine, the average ore contained 8 percent lead and 9 percent zinc (Knopf, 1922, p. 370), and in the 1920's the Simon mine accounted for the bulk of the recorded lead-zinc production of the county.

Uranium

Although no uranium has been produced from Mineral County, it was intensely prospected in the mid-1950's and several areas of anomalous radioactivity have been discovered.

At the Holiday mine in the Fitting district, thorite, huttonite, and uranothorite (thorium and uranium silicates) are concentrated along fractures and disseminated in gouge in crushed and hydrothermally altered granitic rock. Selected samples assay as high as 0.22 percent U_3O_8 and 0.85 percent ThO_2. Another area of radioactive anomaly in altered granitic rocks, for which the mineralogy is not known, is located less than a mile northwest of the Holiday mine. In 1956 both properties were being actively developed on a small scale, and both have stockpiled a few tons of ore, but no shipments had been made up to September 1956.

North of La Panta, at the Amalgamated Uranium Co. pit, carnotite (a hydrous potassium uranium vanadate) occurs as golden yellow concentrations in distinct layers in tuffaceous sandstone that underlies basalt flows. The carnotite appears to be extremely local; a grab sample of the richest looking material assayed 0.4 percent U_3O_8.

West of Teels Marsh an abundance of road building and bulldozer scrapings mark what was the most active area of exploration for radioactive minerals in 1956. The radioactivity comes chiefly from thin limonitic seams in granitic rocks and from thin coatings and seams of green meta-torbernite (hydrous copper uranium phosphate)[11] crystals in Pliocene(?) volcanic breccia. The seams of radioactive material are generally a fraction of an inch to a few inches thick, a few feet long, and widely separated.

Samarskite[12] and euxinite(?)[12] have been found in very small amounts in pegmatite in granitic rock near the south boundary of the county (Lucky Susan claim).

Other Metals

Ten minor iron occurrences are described in Mineral County by Reeves, Shawe, and Kral (1958). Deposits of magnetite and hematite occur chiefly in tactite zones along contacts between

[11]An X-ray powder diffraction pattern of this mineral shows peaks that probably represent cuprosklodowskite (a hydrous copper uranium silicate).

[12]Complex titanate and tantalate niobates containing rare earths and uranium.

limestone and granitic rocks; other deposits have no associated silicate minerals and are direct replacements of limestone or dolomite. The maximum iron content ranges from 40 to 59 percent over a width of at most a few tens of feet. Production has been a few thousand tons, mostly from the Iron Gate property in the Santa Fe district. (See footnote, page 2.)

Several small antimony occurrences have been reported, but the only known production is from the New Potosi mine where bindheimite (a hydrous lead antimonate) and jamesonite (a lead-antimony sulphide) are associated with argentiferous galena. Most of the other antimony occurrences are also bindheimite associated with silver-lead deposits, but stibnite is found in a vein in the Santa Fe district as well as in small amounts associated with the quicksilver deposits of the Pilot Mountains.

In 1916 a small shipment of manganese ore was made from the Black Jack property near Sodaville. The ore came from fissure-filling veins, as much as 2 feet thick, which occur in chert. Manganese minerals present were psilomelane, pyrolusite, and wad in a gangue of calcite, gypsum, and chalcedony. The ore was also tungsten bearing.

NONMETALLIC DEPOSITS

Production of saline minerals from the playa deposits, chiefly at Teels Marsh and Rhodes Salt Marsh in the 1800's and the recent production of fluorspar at the Kaiser (Baxter) mine have given the county a nonmetallic production of about $7,000,000. Other nonmetallic products, such as barite, clay, and aluminous minerals have been produced sporadically in small amounts.

The playa deposits were first exploited for sodium chloride, which was scraped from the surface, but the most important product was borax. At Teels Marsh, natural borax is present, and at Rhodes Salt Marsh ulexite is found in loosely compacted, rounded masses of crystals ("cottonballs") several inches in diameter. The ulexite masses were hand-picked from shallow excavations in the mud of the playa. Rhodes Salt Marsh has also yielded about 20,000 tons of sodium sulphate that was recovered from thenardite (Na_2SO_4). Attempts to recover mirabilite ($Na_2SO_4 \cdot 10H_2O$) from the same playa were unsuccessful. A small amount of sodium carbonate was also recovered from Double Springs Marsh by a system of refining that gave an almost pure anhydrous carbonate product.

Fluorspar with a value of nearly $6,000,000 was produced from the Kaiser (Baxter) mine in the Broken Hills district, which was active almost continuously for about 30 years. The fluorspar fills fissures and interstices and forms a vein system 2 to 8 feet thick in a northeast-trending fault zone, in Tertiary volcanic rocks. A small amount of fluorspar has also been shipped from a property south of Mount Montgomery, where nearly vertical, north-trending veins of fluorite and calcite as much as 18 inches thick cut intermediate volcanic rocks of post-Esmeralda age.

Barite has been produced from properties in the Eagleville district, near Kincaid, and south of Belleville Mountain. All the occurrences are fissure vein deposits, and the total production is over 10,000 tons. Some barite was shipped in 1956 from the Giroux property south of Belleville Mountain. The barite at the Giroux property is associated with chert across a 40-foot width. The vein strikes westward, dips steeply south, and can be traced along the strike for about 300 feet. At the west end the vein thins rapidly and interfingers with the chert.

Several other nonmetallic materials have been produced in the county. Sericitic clay, which is a hydrothermal alteration of intermediate volcanic rocks, has been exploited southwest of Sodaville; about 15,000 tons was shipped to be used as drilling mud. Several thousand tons of bentonitic clay, which came from favorable layers in the Esmeralda formation from the Chiatovich group of claims (Fitting district), have been used as a sealer in dam and reservoir construction. Some gypsum has been shipped from an open pit (Regan mine) in the northwest part of the county. An unknown but probably small production of aluminous minerals, chiefly andalusite, has been made from metamorphosed volcanic rocks of the Excelsior formation from the Dover and Green Talc claims in the Fitting district. Also some serpentine from the Candelaria district has been shipped to the Gabbs area, where it has been used in the processing of the magnesite ores. Small amounts of turquoise and variscite have been produced from small veins, chiefly in the Ordovician chert. None of these properties were active in 1956.

DISTRICTS

Aurora District

The Aurora district, originally known as the Esmeralda district and also called the Cambridge district, is in the southwest part of the county near the California border. The Aurora district, the most productive district of the county (accounting for about 40 percent of the total county production), was discovered in August 1860 by J. M. Brawley, J. M. Cory, and E. R. Hicks while hunting game. The first camp was at Esmeralda, 1 mile south of Aurora, but the camp was soon relocated at Aurora.

Aurora was the county seat of Mono County, California, until a border survey showed the camp was in Nevada. Aurora then became the county seat of Esmeralda County of which Mineral County was at that time a part. By 1864 the population of Aurora was 10,000, but the district began to decline after 1869, although it was productive intermittently till the early 1900's. During the period from 1861 to 1869 nearly $29,500,000 in gold and silver were produced from the district, mostly by the Aurora Mines Co. and the Aurora Consolidated Mining Co. From 1914 to 1918 the district enjoyed a brief resurgence when $1,850,000 in gold and silver were produced chiefly by the Goldfield Consolidated Mines Co.; much of this production was probably from the reworking of tailings and dump material. As late as 1940 a small production was recorded from the district, but in 1956 there was no activity.

Names and the number of individual properties that were active and their relative sizes are generally lost to the record, but there is no doubt that Aurora was a thriving camp in the early 1860's. There were 17 active amalgamation mills in 1864, the largest of which had 30 stamps. The total underground workings are estimated at about 20 miles; the deepest shaft, the Del Monte, was 900 feet deep, and several other shafts were 400 to 500 feet deep. The total amount of ore handled is estimated at 670,000 tons.

The ore bodies occur in branching quartz veins a fraction of an inch to 80 feet thick in pre-Esmeralda volcanic rocks over an outcrop area 2 miles by 1¼ miles. At least 14 veins have been mapped (Hill, 1915, map facing p. 142), which generally strike N. 40° to 50° E. and dip southeast at various degrees; in the northeast part of the district the strike swings around to N. 60° to 80° E. The productive area is in part overlain by barren post-Esmeralda rhyolitic and basaltic (?) rocks.

The veins consist mostly of finely granular white quartz, which in some places has a milky-white porcelain-like appearance. The veins are commonly composed of layers of quartz of different grain sizes, and all the veins contain cavities lined with clear quartz crystals. A more detailed description of the ore from this district is given on pages 72–73.

Bell District

The Bell district, also referred to as the Simon, OMCO, or Cedar Mountain district, comprises all the properties of Cedar Mountain. The major share of all production was gold and silver from quartz veins in pre-Esmeralda volcanic rocks at the Olympic mine, and silver, lead, and zinc from replacement bodies in limestone of the Luning formation at the Simon mine. Each of these mines produced about three quarters of a million dollars, chiefly in the 1920's. Other properties in the district, chiefly gold, silver, tungsten, and mercury, have been very minor producers. In 1956 the only activity in the district was at the Blue Bird and Cedar Chest tungsten properties.

Bovard District

The Bovard district, also known as the Rand or Copper Mountain district is on the east flank of the Gabbs Valley Range about midway between Luning and Rawhide. The district was discovered in 1908 by Al Bovard and other prospectors from Rawhide. About $360,000 in copper, gold, and silver (Vanderburg, 1937, p. 56) were produced from quartz veins in post-Esmeralda (?) volcanic rocks, mostly from 1914 to the late 1920's.

Broken Hills District

The Broken Hills district, in the extreme northeast corner of the county, takes its name from the Broken Hills mine, which was discovered in 1913. A small production of silver and lead is recorded (Vanderburg, 1937, p. 23) from quartz-filled fissure veins and stock-work lenses in post-Esmeralda volcanic rocks. Almost all of the production of the district, however, has come from the Kaiser (Baxter) mine from which fluorspar has been mined almost continuously from the discovery in 1928 to 1957. Nearly $6,000,000 worth of fluorspar has been extracted from fissures in a fault zone in post-Esmeralda volcanic rocks (Thurston, 1946; Matson and Trengove, 1957).

Buena Vista District

The Buena Vista district, also known as the Oneota, Basalt, or Mount Montgomery district, is partly in the south part of the county, chiefly in the White Mountains, but the most productive part of the district is in adjoining Esmeralda County. Within Mineral County, the district includes quartz vein deposits containing gold and silver in post-Esmeralda volcanic rocks, a small quicksilver property worked largely during World War I for cinnabar along faults in rhyolitic volcanic rocks of post-Esmeralda age, a small fissure vein deposit of fluorspar, a contact metamorphic tactite deposit containing scheelite, and prospects for diatomaceous earth in the Esmeralda formation.

Candelaria District

The Candelaria district, also known as the Columbus district, is in the southern part of the county around the old mining camp of Candelaria. The district was discovered in 1863 and the Northern Belle mine, the most productive in the district, was located in 1864. The total production of the district, chiefly in silver, was on the order of $14,000,000 to $20,000,000 (Knopf, 1922, p. 5; Couch and Carpenter, 1943, p. 101), and about half of the production came from the Northern Belle mine. The district was most active from the early 1870's till the early 1890's; during the early 1900's the principal activity was in re-treating tailings, and in 1956 activity was limited to underground mining at the New Potosi mine, and treatment of dump material of the old Northern Belle by the Argentum Mining Co. (See footnote 9, page 72.)

The ore bodies occur in an east-trending vein system that generally parallels bedding in shale of the Candelaria formation; principal ore bodies are 10 to 20 feet wide and are highly oxidized. The ore assayed an average of 60 oz/ton Ag in the early days of mining, but by 1922 the grade was down to 10 to 15 oz/ton Ag. The primary ore, which is principally jamesonite and pyrite with some chalcopyrite and galena in a manganiferous ferrodolomite gangue, was not workable when the district was productive. The north side of the district is bounded by a major post-mineral fault; exploration north of the fault has so far been unsuccessful.[13]

Fitting District

The Fitting district, also known as the Acme or Kincaid (also Kinkead) district, is in the southern part of the Gillis Range. Little is recorded on the history of the Fitting district, but some properties were active as early as 1906. The Fitting district includes a variety of small deposits; production of the district, though not recorded, was probably small. Silver, gold, lead, and copper were produced in the early days from replacement bodies and quartz veins. Aluminous minerals, occurring as replacement masses in volcanic rocks of the Excelsior formation have been developed in various parts of the district, principally before and during World War II. After World War II some prospects were opened on contact metamorphic deposits of magnetite and

[13] The reader is referred to B. M. Page (1959, p. 1-11, 44-63) for further information on this district.

hematite and small amounts of scheelite have been found in other contact metamorphic deposits. In 1956 the principal activity in the district was in connection with uranium at the southeast end of the Gillis range. Hydrothermally altered zones along fracture in granitic rocks contain thorite, huttonite, and uranothorite (uranium and thorium-bearing minerals), but no ore had been shipped by the end of the summer of 1956.

Garfield District

The Garfield district, in the eastern part of the Garfield Hills, is one of the older districts of the county. Development of the Garfield mine began in 1882 and a substantial production of silver, gold, and lead was made from quartz veins(?) in volcanic rocks of the Excelsior formation and limestone of the Luning formation. In the 1920's and 1930's, silver, gold, and lead were also produced from much faulted quartz veins of the Mabel mine, a short distance northwest of the Garfield mine. In addition small amounts of tungsten and copper have been produced from contact metamorphic tactite deposits in this district.

Hawthorne District

The Hawthorne district is in the west part of the Garfield Hills and the east slope of the Wassuk Range southwest of Hawthorne; these two areas have also been referred to as the Pamlico and Lucky Boy districts. Earliest production was from the La Panta and Pamlico areas in the 1870's and 1880's. Gold and silver were produced from quartz veins and oxidized iron-stained masses in volcanic rocks of the Excelsior formation at Pamlico and from a siliceous, ferruginous, gossanlike zone that has replaced the limestone of the Luning formation at La Panta. These two areas may have had a total production of as much as $1,000,000. In 1906 the Lucky Boy veins were discovered by a crew working on roads in the area. These quartz veins in volcanic rocks and marble of the Excelsior formation have accounted for a production of at least $1,000,000 in silver, gold, and lead. Other deposits in the district are small, but include quartz veins worked for gold, silver, copper, and antimony; replacements of limestone by iron minerals; contact metamorphic tactite deposits containing scheelite; and veins of barite. In 1954 a moderate-sized open pit was opened to exploit carnotite, which occurs in stains and streaks in tuffaceous sandstone underlying basalt, north of La Panta. By the end of the summer of 1956, however, there had been no production and the property was idle.

Mount Grant District

The Mount Grant district, also known as the Walker Lake, Cat Creek, and East Walker district, includes all of the Wassuk Range from the north end of Walker Lake south to the Lucky Boy area. The district was a minor producer of principally gold and silver from quartz veins in granitic rocks as early as the 1870's, from properties around Big Indian Mountain and south to Cory Creek. Most of the district is now within the boundary of the Naval Ammunition Depot and access is therefore restricted.

Mountain View District

The Mountain View district, also known as the Granite or Reservation district, is in the north end of the Wassuk Range. In the early 1900's small amounts of gold and silver were produced from quartz veins in granitic rocks. Copper was also produced, chiefly during World War I, from fissure veins in the granitic rocks and sheared limestone of the Excelsior formation. The total recorded production of the district is only a few tens of thousands of dollars.

Pilot Mountains District

The Pilot Mountains district, also referred to as the Sodaville district, is east of Mina. The district is best known for its quicksilver deposits, which began to be exploited after Charles Keough and Thomas Pepper discovered cinnabar in 1913 while chasing lost steers. The cinnabar occurs as fracture fillings, as disseminated grains in fault gouge, and as replacements of limy sedimentary rocks. All the mines and prospects, with the exception of the Lake View property, are beneath northward-dipping, low-angle thrust faults. Numerous small, but in some cases high-grade, cinnabar deposits have been developed in the district and a production of about $600,000 is recorded (Phoenix and Cathcart, 1952, p. 146), although in 1956 there was no activity. In 1916, on the east flank of the Pilot Mountains, scheelite was discovered in tactite that has replaced limestone of the Luning formation along and near contacts with granitic rocks; production from the several properties that have been developed, and which in 1956 were idle, is not known. Small-scale operations have also been carried on in the past in deposits containing gold, silver, and copper minerals.

Regent District

The Regent district, also known as the Rawhide district, is in the north part of the county and includes the area between the old camps of Rawhide and Eagleville. The first activity was in the Eagleville area in the 1870's, but major production followed the discovery of the Rawhide deposits in 1906. From 1908 till the early 1920's Rawhide produced about $1,500,000 in gold and silver (Vanderburg, 1937, p. 60–61) from quartz veins in altered pre-Esmeralda(?) volcanic rocks. This early production has been completely overshadowed, however, by tungsten production, principally in the 1950's. Scheelite in tactite, formed from the replacement of limestone of the Excelsior formation(?) along a granitic contact, was discovered in the area in 1930 by W. H. Leonard; by the early part of 1957, when the chief producer, the Nevada Scheelite mine, shut down, about $12,000,000 in tungsten concentrates had been produced in the area. In addition small deposits have been exploited for iron, quicksilver, antimony, barite, and quartz crystals at various times in this area.

Santa Fe District

The Santa Fe district, also referred to as the Luning district, is in the Gabbs Valley Range northeast of Luning. Properties in the east end of the Garfield Hills, west of Luning, are also considered to be in the Santa Fe district. Copper and silver deposits were discovered in 1879 in the area of the Santa Fe mine, and early exploitation was mainly for silver. The major production of the district, however, was during World War I, when more than $2,000,000 in copper were produced (Vanderburg, 1937, p. 69). The copper occurs both in contact metamorphic deposits associated with tactite developed from limestone of the Luning formation, and as fissure vein deposits along faults. In the north end of the district contact metamorphic deposits have also yielded an unknown amount of scheelite, mostly during and after World War II. The part of the district west of Luning has several small contact metamorphic deposits containing tungsten and copper, but production has been minor. East of Luning several thousand tons of iron ore were produced in the early 1950's from hematite replacement bodies and veins in dolomite of the Luning formation.

Silver Star District

The Silver Star district, also known as the Gold Range, Mina, or Douglas district, and now generally considered to include the Marietta area and the properties west of Teels Marsh (Black Mountain district) is in the Excelsior Mountains. The first activity in the district was in the early 1860's when silver and lead began to be produced from oxidized ores in quartz veins that cut

the sedimentary rocks of the Dunlap formation north of Marietta. In 1893 quartz veins bearing gold and silver were discovered in the Camp Douglas area. The main quartz vein cuts rocks of the Excelsior and Dunlap formations, but to the east some free gold has been extracted from quartz masses in highly altered intermediate volcanic rocks of possible post-Esmeralda age. Massive quartz veins that also cut the Excelsior and Dunlap formations as well as intermediate volcanic rocks of possible post-Esmeralda age were discovered to the south of Camp Douglas in 1916 and first worked for silver. These veins, called the Silver Dyke because of this early silver production, were found at shallow depth to contain abundant scheelite, and during and after World War I more than $1,000,000 in tungsten were produced. As late as the summer of 1956 there was still minor activity at some properties along this vein system. Most of the activity in 1956, however, centered around the uranium prospects west of Teels Marsh. Extensive bulldozing has uncovered thin limonite-stained quartz veins containing radioactive material in granitic rocks, and thin meta-torbernite stringers have been found in granitic rocks and in intermediate volcanic rocks of post-Esmeralda age, but no production had been made by the end of the summer of 1956.

REFERENCES CITED

Anderson, G. H., 1937, Precambrian stratigraphy in the northern Inyo Range, Calif. [abs.]: Geol. Soc. America Proc. 1936, p. 61–62.

Axelrod, D. I., 1956, Mio-Pliocene floras from west-central Nevada: California Univ., Dept. Geol. Sci. Bull., v. 33, 321 p.

Bailey, E. H., and Phoenix, D. A., 1944, Quicksilver deposits in Nevada: Nevada Univ. Bull., v. 38, no. 5, Geology and Mining Ser. no. 41.

Buwalda, J. P., 1914, Tertiary mammal beds of Stewart and Ione Valleys in west-central Nevada: California Univ., Dept. Geol. Sci. Bull., v. 8, p. 335–363.

Callaghan, Eugene, and Gianella, V. P., 1935, The earthquake of January 30, 1934 at Excelsior Mountains, Nevada: Seismol. Soc. America Bull., v. 25, p. 161–168.

Clark, C. W., 1922, Geology and ore deposits of the Santa Fe district, Mineral County, Nevada: California Univ., Dept. Geol. Sci. Bull., v. 14, no. 1, p. 1–74.

Couch, B. F., and Carpenter, J. A., 1943, Nevada's metal and mineral production (1859–1940, inclusive): Nevada Univ. Bull., v. 37, no. 4, Geology and Mining Ser. no. 38.

Evernden, J. F., Curtis, G. H., and Lipson, J., 1957, Potassium-argon dating of igneous rocks: Am. Assoc. Petroleum Geol. Bull., v. 41, no. 9, p. 2120–2127.

Ferguson, H. G., 1924, Geology and ore deposits of the Manhattan district, Nevada: U. S. Geol. Survey Bull. 723, 163 p.

.... 1929, The Mining Districts of Nevada: Econ. Geology, v. 24, no. 2, p. 115–148.

Ferguson, H. G., and Cathcart, S. H., 1954, Geologic map of the Round Mountain quadrangle, Nevada: U. S. Geol. Survey Geol. Quad. Map Series, GQ 40.

Ferguson, H. G., and Muller, S. W., 1949, Structural geology of the Hawthorne and Tonopah quadrangles, Nevada: U. S. Geol. Survey Prof. Paper 216, 53 p.

Ferguson, H. G., Muller, S. W., and Cathcart, S. H., 1953, Geologic map of the Coaldale quadrangle, Nevada: U. S. Geol. Survey Geol. Quad. Map Series, GQ 23.

.... 1954, Geologic map of the Mina quadrangle, Nevada: U. S. Geol. Survey Geol. Quad. Map Series, GQ 45.

Ferguson, H. G., Roberts, R. J., and Muller, S. W., 1952, Geologic map of the Golconda quadrangle, Nevada: U. S. Geol. Survey Geol. Quad. Map Series, GQ 15.

Foshag, W. F., 1927, Quicksilver deposits of the Pilot Mountains, Mineral County, Nevada: U. S. Geol. Survey Bull. 795, pt. 1, p. 113–123.

Geehan, R. W., and Trengove, R. R., 1950, Investigation of Nevada Scheelite, Inc., deposit, Mineral County, Nevada: U. S. Bur. Mines Rept. Inv. 4681, 13 p.

Gianella, V. P., 1945, Bibliography of geologic literature of Nevada, and Prince, R. W., Bibliography of geologic maps of Nevada areas: Nevada Univ. Bull., v. 39, no. 6, Geology and Mining Ser. no. 43, 205 p.

Gianella, V. P., and Callaghan, Eugene, 1934, The earthquake of December 20, 1932, at Cedar Mountain, Nevada, and its bearing on the genesis of Basin Range structure: Jour. Geology, v. 42, p. 1–22.

Gilbert, C. M., 1941, Late Tertiary geology southeast of Mono Lake, Calif.: Geol. Soc. America Bull., v. 52, p. 781–815.

Hess, F. L., and Larsen, E. S., 1921, Contact-metamorphic tungsten deposits of the United States: U. S. Geol. Survey Bull. 725-D, p. 245–309.

Hill, J. M., 1915, Some mining districts in northeastern California and northwestern Nevada: U. S. Geol. Survey Bull. 594.

Hobbs, W. H., 1910, The earthquake of 1872 in Owens Valley, Calif.: Beitr. Geophysik bd. 10, p. 379.

Jackson, E. D., and Ross, D. C., 1956, A technique for modal analyses of medium- and coarse-grained (3–10 mm) rocks: Am. Mineralogist, v. 41, p. 648–651.

Johannsen, Albert, 1939, A descriptive petrography of the igneous rocks, Vol. I: Chicago, Univ. of Chicago Press.

Kerr, P. F., 1936, The tungsten mineralization at Silver Dyke, Nevada: Nevada Univ. Bull. v. 30, no. 5, Bull. Nev. Bur. Mines and Mackay School of Mines, No. 28, 67 p.

Knopf, Adolph, 1921, Ore deposits of Cedar Mountain, Mineral County, Nevada: U. S. Geol. Survey Bull. 725, p. 361–382.

.... 1922, The Candelaria silver district, Nevada: U. S. Geol. Survey Bull. 735, p. 1–22.

Larsen, E. S., Jr., Keevil, N. B., and Harrison, H. C., 1952, Method for determining the age of igneous rocks using the accessory minerals: Geol. Soc. America Bull., v. 63, p. 1045–1052.

Lincoln, F. C., 1923, Mining districts and mineral resources of Nevada: Reno, Nevada Newsletter Publishing Co., p. 137–157.

Locke, Augustus, Billingsley, P. R., and Mayo, E. B., 1940, Sierra Nevada tectonic pattern: Geol. Soc. America Bull., v. 51, p. 513–539.

Mathews, W. H., 1951, A useful method for determining approximate composition of fine-grained igneous rocks: Am. Mineralogist, v. 36, p. 92–101.

Matson, E. J., and Trengove, R. R., 1957, Investigation of fluorspar deposit, Kaiser Mine, Mineral County, Nevada: U. S. Bur. Mines Rept. Inv. 5344.

Merriam, C. W., and Anderson, C. A. 1942, Reconnaissance survey of the Roberts Mountains, Nevada: Geol. Soc. America Bull., v. 53, p. 1675–1727.

Muller, S. W., 1936, Triassic coral reefs in Nevada: Am. Jour. Sci., 5th ser., v. 31, p. 202–208.

Muller, S. W., and Ferguson, H. G., 1936, Triassic and Lower Jurassic formations of west central Nevada: Geol. Soc. America Bull., v. 47, p. 241–251.

———— 1939, Mesozoic stratigraphy of the Hawthorne and Tonopah quadrangles, Nevada: Geol. Soc. America Bull., v. 50, p. 1573–1624.

Nockolds, S. R., 1954, Average chemical compositions of some igneous rocks: Geol. Soc. America Bull., v. 65, p. 1007–1032.

Nockolds, S. R., and Allen, R., 1954, The geochemistry of some igneous rock series, pt. II: Geochim. et Cosmochim. Acta. v. 5, no. 6, p. 245–285.

Page, B. M., 1959, Geology of the Candelaria mining district, Mineral County, Nevada: Nevada Bur. Mines Bull. 56.

Phoenix, D. A., and Cathcart, J. B., 1952, Quicksilver deposits in the southern Pilot Mountains, Mineral County, Nevada: U. S. Geol. Survey Bull. 973-D, p. 143–171.

Reeves, R. G., Shawe, F. R., Kral, V. E., 1958, Iron ore deposits of Nevada, Part B: Nevada Bur. Mines Bull. 53.

Rinehart, C. D., and Ross, D. C., 1957, Geologic map of the Casa Diablo Mountain quadrangle, California: U. S. Geol. Survey Geol. Quad. Map Series, GQ 99.

Rinehart, C. D., Ross, D. C., and Huber, N. K., 1959, Paleozoic and Mesozoic fossils in a thick stratigraphic section in the eastern Sierra Nevada, California: Geol. Soc. America Bull., v. 70, p. 941–945.

Rittmann, A., 1952, Nomenclature of volcanic rocks: Bull. volcanol., Series II, Tome XII, p. 75–102.

Russell, I. C., 1885, Geological history of Lake Lahontan, a Quaternary lake of northwestern Nevada: U. S. Geol. Survey Mon. 11.

Slemmons, D. B., 1957, Geological effects of the Dixie Valley-Fairview Peak, Nevada, earthquakes of December 16, 1954: Seismol. Soc. Bull., vol. 47, no. p. 353–375.

Smith, J. R., and Yoder, H. S., Jr., 1956, Variations in X-ray powder diffraction patterns of plagioclase feldspars: Am. Mineralogist, v. 41, p. 632–647.

Spurr, J. E., 1903, Descriptive geology of Nevada south of the fortieth parallel and adjacent portions of California: U. S. Geol. Survey Bull. 208, p. 103–117.

Stirton, R. A., 1940, The Nevada Miocene and Pliocene mammalian faunas as faunal units: Sixth Pacific Sci. Cong. 1939, Proc., v. 2, p. 627–640.

Thurston, W. R., 1946, Preliminary report on the Baxter fluorspar deposit near Broken Hills, Mineral County, Nevada: U. S. Geol. Survey Strategic Minerals Inv. Prelim. Rept. 3-196.

Turner, H. W., 1900, The Esmeralda formation, a fresh-water lake deposit: U. S. Geol. Survey Ann. Rept. 21, pt. 2, p. 197–208.

———— 1902, A sketch of the historical geology of Esmeralda County, Nevada: Am. Geol. v. 29, p. 261–272.

———— 1909, Geology of the Silver Peak quadrangle, Nevada: Geol. Soc. America Bull. v. 20, p. 223–264.

Vanderburg, W. O., 1937, Reconnaissance of mining districts in Mineral County, Nevada: U. S. Bur. Mines Inf. Circ. 6941, 79 p.

Van Houten, F. B., 1956, Reconnaissance of Cenozoic sedimentary rocks of Nevada: Am. Assoc. Petroleum Geologists Bull., v. 40, no. 12, p. 2801–2825.

Walcott, C. D., 1916, Cambrian trilobites: Nat. Acad. Sci. Proc. 2:101.

Whitney, J. D., 1866, Remarks on the geology of the State of Nevada: Calif. Acad. Nat. Sci. Proc., v. 3, p. 268–270.

INDEX

First edition, fourth printing, 1992, 1500 copies
Color plates printed by A. Carlisle, 1080 Bible Way, Reno, NV
Text, black and white plates, and envelope printed by DynaGraphic Printing, 2001 Timber Way, Reno, NV

For sale by the Nevada Bureau of Mines and Geology, University of Nevada, Reno, NV 89557-0088

The Nevada Bureau of Mines and Geology (NBMG) is part of the Mackay School of Mines at the University of Nevada, Reno and is the state geological survey. NBMG scientists conduct research and publish reports on mineral resources and various aspects of general, environmental, and engineering geology.

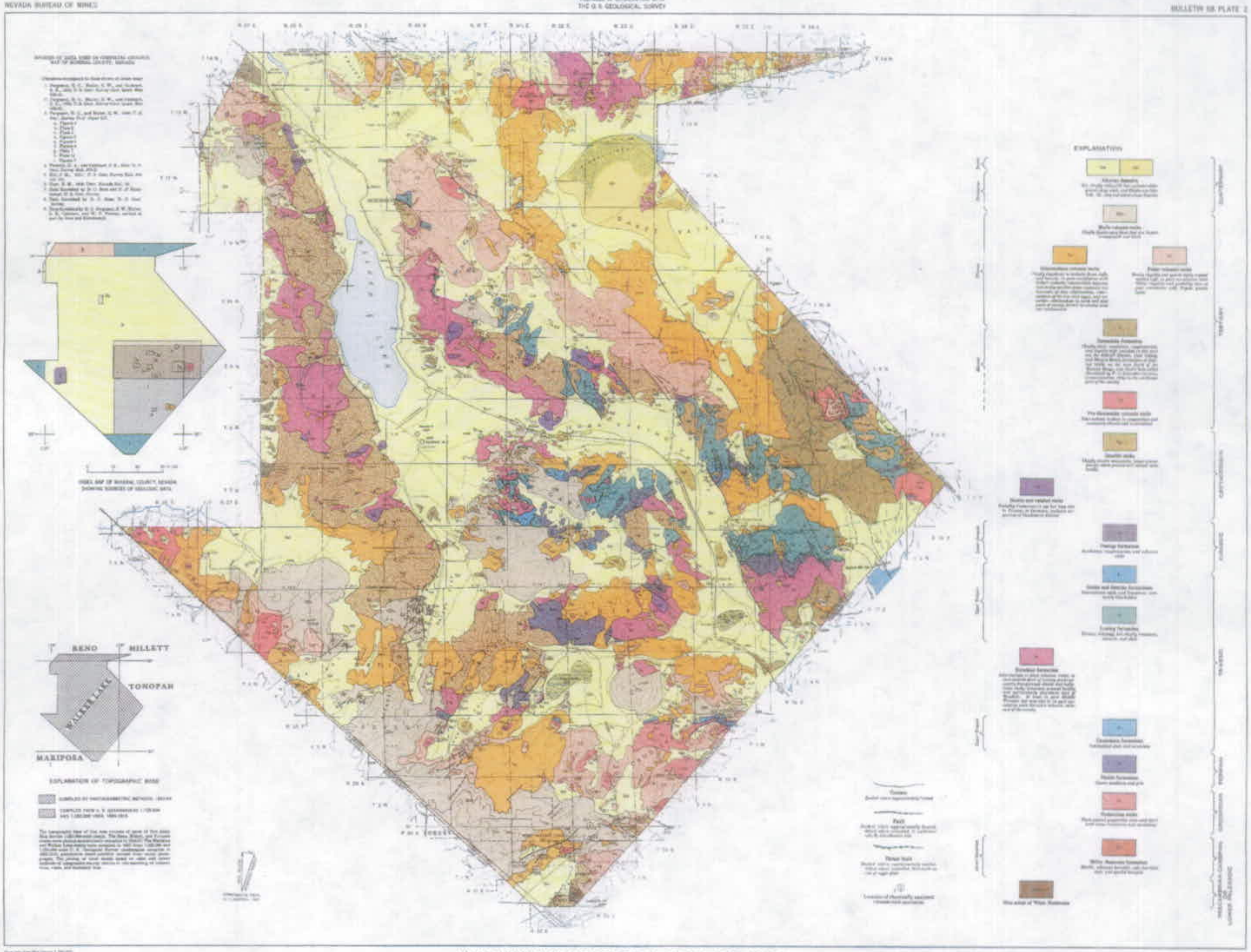
Current activities in mineral resources and general geology include detailed geologic mapping and stratigraphic studies in Nevada, comparative studies of bulk mineable precious-metal deposits, geochemical investigations of mining districts, resource assessments, igneous petrologic studies, hydrothermal experiments, research on the origin of hydrothermal platinum-group-element occurrences, and examination of the origin and distribution of borate deposits in Nevada.

Environmental, engineering, and urban geology projects include investigations of earthquake hazards and related aspects of neotectonics, examination of issues involved in siting nuclear and hazardous wastes, mapping of geomorphic features, radon hazard studies, studies of landslide hazards, and investigation of land subsidence in Las Vegas Valley.

Geologic information activities include creating and updating databases on mining districts, active mines and prospects, and geothermal and petroleum exploration and production; implementation and development of statewide geographic information systems; and maintenance of core and cuttings facilities, rock and mineral collections for research, aerial photographic imagery and maps, and extensive files on Nevada geology and resources.

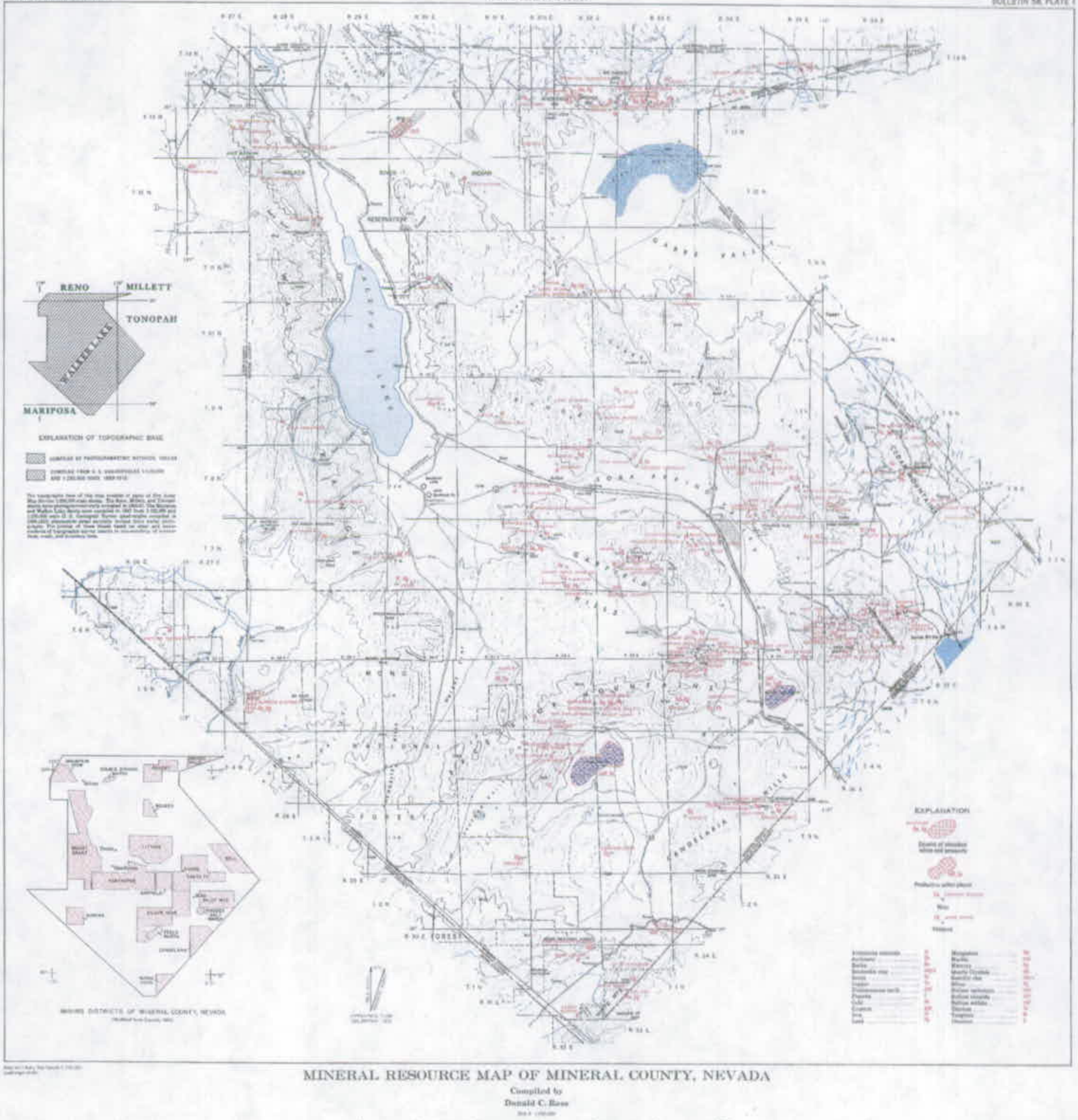
NBMG cooperates with numerous state and federal agencies in providing geologic and resource information and in conducting research. Research results are published as NBMG bulletins, reports, maps, and special publications as well as in federal publications and scientific journals. In addition to addressing the needs for geologic information by conducting research, publishing reports and maps, and creating computer databases, staff members assist the public, industry, and government agencies by answering specific questions regarding Nevada geology and resources and by providing some chemical and mineralogical analyses.

Individuals interested in Nevada geology are encouraged to visit or write NBMG or call (702) 784-6691. NBMG offices are located in the west wing of the Scrugham Engineering-Mines Building on the University of Nevada, Reno campus. When visiting NBMG by car please stop at the information booth just inside the Center Street entrance on the south end of the campus. The attendant will issue you a temporary parking permit and give you directions to parking areas and the NBMG offices. Address mail to: Director/State Geologist, Nevada Bureau of Mines and Geology/178, University of Nevada, Reno, NV 89557-0088. Our fax number is (702) 784-1709. A publication list will be sent upon request.



GEOLOGIC MAP OF MINERAL COUNTY, NEVADA

Compiled by
Donald C. Ross



MINERAL RESOURCE MAP OF MINERAL COUNTY, NEVADA

Compiled by
Donald C. Ross